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ORIGINAL ARTICLES.

I.—Eminent Living Geologists: Professor Charles Lapworth, LL.D., F.R.S., F.G.S., of the Birmingham University.

(WITH A PORTRAIT, PLATE V.)

CHARLES LAPWORTH was born in 1842 at Faringdon, in Berkshire. Five years afterwards his parents removed to Lower Newton, one of the farms rented by his grandfather. He attended the country school at Buckland village, about two miles off, and the vicar of the parish, the Rev. Joseph Moore, finding him an omnivorous reader, generously lent him books from his own library and practically directed his early education. At the age of 15 he became a pupil teacher in the school, and in the year 1862 entered the Training College at Culham, near Oxford, passing out thence in 1864 with a first-class Government certificate. Of the posts as schoolmaster which were then offered him he selected that connected with the Episcopal Church at Galashiels, because it would give him a home and work in the fascinating borderland of Sir Walter Scott. This post he retained for eleven years, and was married in 1869 to the daughter of Mr. Walter Sanderson.

His holidays were spent in wandering over the Border region, and in the year 1869, in company with his friend Mr. James Wilson, he began the study of the geology of the district round the town, zest being given to the work by the discovery of fossils in rocks which had hitherto been considered barren. His first paper, "On the Silurian Rocks of Galashiels," was read before the Geological Society of Edinburgh in 1870, and was published by that Society and in the pages of the Geological Magazine. While at Galashiels he wrote his paper "On an Improved Classification of the Rhabdophora" (1873).

In 1875 he was appointed to one of the assistant masterships in the Madras College, St. Andrews, and from that year until 1881 he continued to teach subjects which, though not absolutely uncongenial to him, gave little or no scope for scientific teaching or scientific methods. But the post afforded much that he wanted, longer holiday-time for research, greater leisure for reading, and, above all, frequent association with such friends as Nicholson and the literary

and scientific men of the place. His holidays were spent in continuing his work on the stratigraphy and fossils of the Scottish Uplands. Here he wrote his papers on the Moffat Series, the Scottish Monograptidæ, the Distribution of the Rhabdophora, and others.

But in 1881 came a welcome change, and he was able to throw his entire energy into science, scientific teaching, and geology. His researches and papers had by this time made his name familiar to workers in the older fossiliferous rocks, and, backed by many of the most famous British and foreign geologists of the day, he applied for, and was elected to fill, the newly established Chair of Geology and Mineralogy at the Mason College, Birmingham, his title being afterwards modified at his own request to Professor of Geology and Physiography. He at once plunged into the teaching work of his Chair, but the greater leisure and opportunities the post afforded allowed him to complete and publish his Girvan paper, to carry out serious field-work in the Highlands of Scotland, to make discoveries in the Midland district, and, later on, to begin that work in the Ordovician districts of Shropshire which was to lead him down, stage by stage, to the uttermost depths of the Longmyndian rocks. As the years have gone on he has practically devoted all his energies to geological and geographical work—not only as a teacher, investigator, and writer, but as outside lecturer, textbook writer, university examiner, scientific adviser, and in the other multifarious obligations which appertain to the Geological Professor of modern days.

Lapworth was elected a Fellow of the Geological Society of London in 1872, was awarded the Murchison Fund in 1878, the Lyell Fund in 1882 and 1884, the Bigsby Gold Medal in 1887, the Wollaston Medal in 1899, and went on the Council of the Society in 1894. The honorary degree of LL.D. was conferred on him by the University of Aberdeen in 1884. In 1888 he was elected a Fellow of the Royal Society, receiving a Royal Medal in 1891, and serving on the Council in 1895–1896. He has acted as examiner in Geology to the Universities of Oxford, Cambridge, London, Victoria, and Wales, was President of the Geological Section of the British Association in 1892, is an honorary member of the Geologists' Association and other scientific societies at home and abroad, and is now President of the Geological Society of Glasgow.

In considering the general scope of Professor Lapworth's work and the bearing of its results, it will be well to divide it into four branches, Field Geology, Geology in the Laboratory and Study, Teaching, and Applied Geology.

1. *Work in the Field.*

The development of the geology of the Southern Uplands may be said to form the keynote of Lapworth's field-work. The stratigraphy of highly complicated districts had already been frequently studied in outline; and in mountain districts it had been pointed out again and again that the apparent sequence was not to be trusted. But the detailed unravelling of such districts had been seldom attempted

with any success. It is well known that previous to Lapworth's researches the Silurian rocks of the Southern Uplands had been considered to be a normal ascending sequence of greywackés, of enormous thickness, interrupted by occasional thin seams of black, graptolitic shale. As the graptolite fauna of each shale mass was broadly the same as that of every other mass, it was naturally considered that the Upland series had been rapidly deposited, without any important organic change taking place from base to summit; and that, consequently, graptolites were of no use for zone work. Important negative conclusions in the matter of evolution followed as a corollary.

One of the first things that made Lapworth suspect that things were not as they seemed was, that graptolites of highly divergent types, though found near together, were never met with on the same slab of rock; and this was followed by the discovery that there was always a difference, sometimes generic and always specific, in the faunas of contiguous and successive bands in each shale mass.

When he had discovered that on proceeding downwards from the greywacké of Dobb's Linn a definite sequence of graptolites was met with down to a certain point, he hit upon the important fact that a corresponding and practically identical sequence was met with also, but in inverted order, in descending beyond this point until greywackés were again reached. It is said that, on first suspecting this, Lapworth rushed into the field and, reaching Dobb's Linn in the twilight, he rapidly collected one series of graptolites in descending to the critical point which he placed in his right-hand pockets, and another in descending below it which he put in the left-hand pockets; he then carried both series off to his lodgings to compare in the lamplight. The comparison verified his hypothesis, and he now held the proof that in this locality, at all events, half the rock succession was inverted. Indeed, he had got hold of the right end of the clue which subsequently enabled him to unravel the complicated stratigraphy of the region. To this task he now devoted his spare time for seven or eight years, nor did he stop until he had followed the divisions of the Moffat Shale from sea to sea, mapping the critical areas in great detail, sometimes on the 6 inch scale, but in most instances surveying and constructing his own larger scale maps of the special localities, in which he could insert the zones as they occurred in the field. At the same time he acquired the large collection of graptolites necessary to verify his conclusions and complete his knowledge of the fauna.

Although probably himself satisfied that the hypothesis of a chronological sequence of graptolite zones, which worked so well in elucidating the complicated structure of the Moffat region, must be in the main a correct one for the Uplands generally, Lapworth proceeded to apply the severest test that he could think of to his conclusions. For that purpose he selected next the Girvan area, where the rocks have a different facies and graptolite-bearing seams are rare or subordinate, but where it was already known that there is a vast array of other Silurian fossils and very

great lithological variety in the strata. Here Lapworth found his work much facilitated by the rich collections of fossils already made from this district by Mrs. Robert Gray, and he was free to devote himself to working out the stratigraphy and collecting graptolites. The outcome of the stratigraphical work on the Girvan succession was published in a paper to the Geological Society in 1882, but the publication of some of the broader structural questions connected with the surrounding area and the Uplands as a whole was deferred for some years, and was then published as a paper on the Ballantrae Rocks in the GEOLOGICAL MAGAZINE in 1889.

It is needless to say that the Girvan work entirely confirmed that of Moffat in all particulars. The succession of rocks in the new area, although more than twenty times the thickness, was found to tally with that of Moffat, the chronological order of the fossils common to the two areas agreed, the succession of physical changes was coincident, and the type of structure indicated that Moffat and Girvan were parts of the same grand region of deposition and of the same great system of earth-movement. It is characteristic of Lapworth, however, that not one of these coincidences is so much as hinted at in his first Girvan paper. The local facts were described and the local inferences drawn, but the reader was left to compare the Girvan and Moffat phenomena, and to draw from them the inevitable conclusions for himself.

Needless also to remind readers of the GEOLOGICAL MAGAZINE that the officers of the Geological Survey, unhampered in their methods and possessed of detailed maps to work with, have in the course of time entirely confirmed Lapworth's conclusions in the two areas, and, by adopting the zonal method which he initiated with such success, they have been able in some particulars to advance beyond his original conclusions. The great Survey Memoir on the Scottish Uplands is not only the record of a fine piece of survey work, but a monument to the genius of the man who made it possible.

This Upland work, together with its demonstration of the value of the graptolite as a zone index, brought Lapworth into conflict with the views of many of the established authorities of the time. Particularly was this the case with the veteran Barrande, whose well-known theory of 'Colonies' had been founded to get over difficulties almost precisely similar to those which existed in South Scotland. Barrande devoted his final "Defense des Colonies, No. 5," to the matter, but, far from subscribing to Lapworth's views, he maintained the validity of his colonies and even named a new one after his antagonist. But, neither on this nor on any other occasion, has Lapworth turned aside from his course to indulge in controversy; he has simply gone straight on with his work.

Having demonstrated that the Southern Uplands were the relic of a wide area of orogenic movement, Lapworth was next naturally drawn to a region in which earth-movement had had even greater play than in the Uplands. The experience already gained would constitute the basis of his researches and enable him to get over preliminary difficulties, while he would learn the effects of a much

more complicated movement, carried on through a longer period, over a greater area, and to a higher degree than in the south. Hence he started work in 1882 in the Durness-Eriboll district of the Scottish Highlands, working after the same model as before, by selecting definite bands of rock, zoning them, and running them as clues through the complex. Here, however, fossils ceased to be the guide, and it was only by noticing lithological differences that the selected strata could be individualized and recognized from point to point. These were mapped in detail, as before, in order to bring out the structure. In a short time Lapworth had ascertained the true succession amongst the unaltered rock-formations, and made out enough of the tectonic facts to destroy once for all the old idea of an upward succession into the so-called 'newer gneiss.' The structure was of Alpine character, and "the stratigraphical phenomena identical with those developed by Rogers, Suess, Heim, and Brögger in extra-British mountain regions." These results were published in 1883 in the earlier pages of "The Secret of the Highlands." In the later pages he introduced, summarized, and discussed the phenomena and principles of mountain structure developed in Heim's great work on "Gebirgsbildung," in preparation for the understanding of the higher stages of the Highland work. Corresponding stratigraphical results had been simultaneously obtained by Callaway in the Assynt district, and the Geological Survey began their mapping of the North-West Highlands. The Surveyors followed the zonal method, obtained the same non-metamorphic succession, and in the course of a few years not only demonstrated the Alpine structure of the region, but proved the existence of some of the grandest and most important phenomena known to the world of geology. It is to be hoped that at no distant date we may see in a Survey Memoir on the Highlands a worthy companion volume to the great Upland Memoir.

Lapworth returned to the Highlands in the following Summer, but the plain living and hard thinking brought on a serious illness which prevented him from writing further on the tectonic side of the subject. But not before he had reached conclusions on dynamic metamorphism somewhat similar to those arrived at on other grounds by Lossen in the Harz and Lehmann in the Erzgebirge. These views were summarized in a short paper published by the Geologists' Association (1885), and more fully developed later on in his edition of Page's "Introduction to Geology" and elsewhere.

When Professor Lapworth went to Birmingham it was thought that the fossiliferous Llandovery rocks of the Lickey Hills were the oldest rocks in the Central Midlands. But in the year 1882, aware that the earlier geologists had paralleled the quartzites of Nuneaton and the Lickey with those of the Wrekin and Caradoc, which had later on been shown by Callaway to be at least older than the Upper Cambrian, he suggested that these rocks were probably the outstanding parts of a buried land surface older than the Silurian. In less than a month actual proofs of this view were discovered at the Lickey by Mr. F. T. S. Houghton and by Lapworth himself.

The same year Lapworth and Mr. Jerome Harrison proved that the rocks of Nuneaton, Hartshill, and Atherstone, instead of being Coal-measures and Millstone Grit as laid down on the published maps, were also parts of this buried land and of Cambrian age. This was established by Lapworth's finding of Cambrian fossils in the shales of Stockingford, above the Quartzite, and volcanic rocks of Uriconian type underneath it. These discoveries, of course, demanded fresh maps of the districts implicated; in 1886 the officers of the Survey came down, satisfied themselves as to their correctness in the Nuneaton district, and brought out new editions of their maps in order to include them. In 1898 the same thing was done for the Lickey Hills, the official surveyor being on this occasion an old student of Lapworth's, trained by him on those very hills. The more crucial parts of both these districts had already been mapped in detail by Professor Lapworth, sometimes in company with his students.

The further discovery of calcareous beds in the upper part of the Nuneaton Quartzite, by Dr. T. Stacey Wilson, led to the searching of the rocks for fossils along this line of country by Professor Lapworth, and the discovery of a bed of limestone bearing *Hyolites* and other fossils characteristic of the lowest fossiliferous Cambrian or Etcheminian horizons of America and elsewhere (1897).

In 1886 work was begun in the Shelve district of Shropshire, and in the course of two or three years the sequence was made out and compared with that of South Scotland, North Wales, and Scandinavia (1887, 1894). In later years the more detailed mapping of the greater part of that area has elucidated its structure, while at the same time the more complicated Caradoc region on the east of the Longmynd has been studied. Failing to find in that district a satisfactory base to the Ordovician System, the Cambrian rocks were next dealt with, the first outcome being the discovery of *Olenellus* and its accompanying fauna at the top of the basal Shropshire Quartzite (1888). This discovery resulted directly in the finding of the equivalent of the *Olenellus* Limestone at Nuneaton, and indirectly in the finding of *Olenellus* in the 'Fucoid Beds' of North Scotland. Thus a definite Lower Cambrian horizon became marked out over a large area, and the base of the Cambrian System was drawn at the bottom of the Quartzite.

It was, however, soon found impossible to complete the study of the Lower Palæozoic sequence of this region without mapping the underlying floor of Dr. Callaway's Uriconian and Longmyndian rocks and working out the sequence and structure of the Harlech anticline, which has been more or less completed by Lapworth and his friend Dr. Stacey Wilson.

This bald enumeration of thirty-three years' field-work naturally leads to a brief consideration of the causes which have contributed to its success. The principal reasons appear to the writer to be the following:—(1) Careful mapping on lines similar to those adopted by the Geological Survey, but usually in greater detail; the difficult areas being done on as large a scale as possible, and

the crucial points visited many times over until their structure has become quite clear. To this class of work Lapworth was naturally drawn by his early interest in physical geography, when he was always seeking to explain the causes underlying observed phenomena. His untiring industry, actuated by what has been called 'a genius for stratigraphy' and a good eye for a country, filled even the dullest routine work with interest. (2) The observation of minute lithological changes whether in a vertical or a lateral direction. (3) The zonal collection and identification of fossils from every band which yields them. (4) The capacity to 'see solid' into a map so that a complete picture of the solid structure is constantly present before the mind. (5) The careful thinking out of the bearing of facts observed and entered on the maps in the light of many possible theoretical explanations, until a consistent hypothesis is hit upon by the method of trial and error. (6) But, above all, the power to realize vividly the conditions which might have given rise to the observed phenomena; so that in imagination he sees them at work and studies their results. It has been said more than once that it is of no use to contradict Lapworth when he has made up his mind on a geological question, "because he was there when the rocks were made."

2. *Work in the Laboratory and Study.*

Lapworth's investigations on the graptolites must be regarded as the outcome of his work in the Uplands, for from this region he collected and worked through hosts of these fossils, the difficulty of satisfactorily identifying species causing him to save all specimens which might lead to unmistakeable identification or throw light on the life-history of these extinct hydrozoa. At the time he began the study the classification of the graptolites in general use was in almost as unsatisfactory a state as the grouping of the rocks, and the two studies had to be carried on concurrently. But while this increased the labour it intensified the interest, and directed attention to points which might otherwise have been overlooked. The graptolites, among which excellent work was also being done by Hopkinson and Nicholson, soon began to sort themselves out; the rock-formations resisted much longer. Lapworth's study and comparison of his own collection, with those already made in other parts of the world, gave rise to his paper "On an Improved Classification of the Rhabdophora," which was published in 1873, and has since been either accepted as the standard to which graptolites are referred, or has formed the basis upon which the newer provisional classifications are founded. Having acquired a profound belief in the value of graptolite species for zone work, he took every opportunity for several years to collect specimens not only in Scotland but in Wales and Ireland, and of studying the works and collections of others, thus accumulating a vast amount of material for his invaluable treatise on "The Geological Distribution of the Rhabdophora" (1879–80), in which for the first time not only are graptolite zones established over Britain, but the distribution of the zones and their contents all over

the world, so far as was then possible, was analysed, tabulated, and described, and the inference established that the graptolite was as reliable as the ammonite for a working stratigraphical index.

Some years elapsed before these conclusions were accepted in their entirety, except by his friends and fellow-workers in Scandinavia, but gradually his methods were taken up by first one and then another of the younger men in Britain and abroad, until, eventually, students of Palæozoic rocks in all parts were sending Lapworth graptolites for identification, and numerous papers and appendices to papers, containing descriptions of new species and identifications of old ones, were published (1875, 1877, 1881). St. David's, County Down, Central Wales, and many other British districts soon yielded graptolites in sufficient quantity to enable the rock-horizons to be ascertained, and though the results sometimes conflicted with the apparent stratigraphy, that was only so much the worse for appearances and so much the better for facts. From foreign countries and from the Colonies specimens came in for identification and as tests of the mapping. Led insensibly thereto by their own discoveries, palæontologists fell into the habit of similarly classifying their fossils and employing them zonally, so that now the despised graptolite of thirty years ago has become universally accepted as the guide to the zonal order of the older fossiliferous rocks.

The Upland work demonstrated that graptolites had not been standing still while all the Silurian rocks were being deposited, but that there had been continual variation, modification, and evolution. This, with the material subsequently accumulated, bearing on the life-history and habitats of the group and the probable causes to which their evolution was due, enabled Professor Lapworth to contribute to a paper by Walther an important communication on the "Mode of Life of the Graptolites" (1897), in which he advanced the theory that whilst the earliest and dendroid graptolites stood upright in shallow shore water, the later and more typical forms (Rhabdophora) hung suspended from floating sargasso-like seaweeds, so that they were drifted over the sea-waters as 'pseudo-plankton' by currents, and their skeletons thus distributed more or less all over the sea-bed. This gave origin to the wide distribution of graptolite zones, and also, in all probability, was the actuating cause of the morphological evolution of the families and genera of Rhabdophora, as well as the explanation of their abundance in black carbonaceous shales.

Later on Dr. Lapworth undertook the task of describing the British graptolites for the Palæontographical Society, and devoted a large amount of time to the correct drawing and illustrating of the fossils. Numerous experiments in the reproduction of illustrations were tried and are still being tried, and a new form of microscope (the Lapworth-Parkes) was worked out, by which even large specimens can be drawn in great detail, and under such conditions of lighting that no important point of structure is omitted, the main purpose being to present the object as like nature as possible without

any interposition of the personality of the artist. The large-scale drawings are afterwards reduced by means of photography to the natural size of the fossil. The monograph is now being written and illustrated jointly by Miss Elles and Miss Wood under Dr. Lapworth's editorship.

A rapid reader, with the faculty of quickly 'tearing the heart out of a book,' of 'spotting' mistakes into which a writer may have fallen, and of seeing the importance of an author's facts even when his interpretation is wrong, Lapworth goes to his work, whether in the field or the study, with a clear view of the problems to be faced and a knowledge of the crucial points for testing hypotheses, of which he has generally plenty on hand ready for immediate use. Thus it often happens that the main points in a research are settled in a few days, but, meanwhile, a host of new problems have arisen, and for their solution it is necessary to work out the district thoroughly. As Professor Marcel Bertrand pertinently puts it, Lapworth's widest results have been often arrived at "à l'aide de ces outils qu'il a forgés lui-même et que d'autres eussent dédaignés." This, coupled with a keen zest for outdoor work, which carries him out into the field on every fine day and most wet ones if they happen to be Saturdays or in holiday-time, accounts for the large amount of single-handed field-work that he has accomplished. His own explanation is, that it is simply the natural outcome of a childhood spent among books in lieu of companions, of a manhood blessed by the constant encouragement and aid of his friends, and of almost a lifetime passed in the sympathy of his pupils.

The keenness in understanding and appreciating the work of others, which led Lapworth to abstract parts of Heim's Alpine treatise in order to show that there was nothing new in the principles employed in his own Highland work except their application to that district, and which is further exemplified in his appreciative memoirs of his early scientific friends Linnarsson, Nicholson, and Crosskey, is accompanied by a vivid imagination which enables him to visualize accurately the subjects on which he reads, a power of recognizing connecting links between severed lines of enquiry, and a faculty for picking out those exceptions to laws which indicate the existence of some greater law including the less.

In his two papers "On the Tripartite Classification of the Older Palæozoic Rocks" (1879) and "The Close of the Highland Controversy" (1885) we see Lapworth in another light. In these tactful endeavours to still controversy, neither of them fruitless, we see such a grip of the subjects dealt with as to indicate complete mastery of the literature, independent thought, extreme care and skill in the presentation of conclusions and suggestions, and just that gentle suspicion of the authority which his own work on the subjects dealt with entitled him to assert. In each case Lapworth brought out the best points in the discoveries of the rival pioneers, and showed that of such points those which were vital were generally the common property of the rivals and their schools; but he indicated most firmly that past

history and dead controversy must never be allowed to clog the wheels of progress. In both cases the old men had built a firm platform on which the new men were standing ready for the next rush forward; they should not be too much concerned about the building of that platform when once they are convinced about its soundness, nor must they spend all their time quarrelling as to how its parts were first put together. The great thing for them is to make the next advance and to see that it is unhampered by questions of authority or nomenclature. It is largely due to the moderate tone of these papers that the Highland question is now no more, and that the term 'Ordovician' has been adopted nearly all over the world.

The appointment of Professor Lapworth to the presidency of the Geological Section of the British Association at Edinburgh in 1892 necessitated the preparation of an address, and gave him the opportunity of welding together his researches and theories in geology and geography by dealing with the rock-fold, the 'wedding-ring' of the two sciences. After treating of the physical and geological aspects of the structure he passed on to apply it to the making of mountains and continents, and to connect it with the form and structure of the earth itself. Further developments of this subject in time and space were communicated to the Geologists' Association and the Royal Geographical Society respectively, and have been treated of in college and other lectures on tectonic geology.

As Lapworth's South Scottish work came into contact with and made Barrande's theory of 'Colonies' untenable, so his views on the effects of mountain movement conflicted with Richthofen's beautiful theory of the coral-reef origin of the limestone masses of the Dolomites. A paper on the Dolomite country by Miss Ogilvie (Mrs. Gordon) was read before Baron von Richthofen, who was present at the Edinburgh meeting, and Lapworth, who had long considered the matter, although he had never visited the ground, took the opportunity of stating his belief that the so-called reef structures were the result of crust-deformation and not of original deposition, and that the associated igneous rocks belonged to the period of movement. The work and conclusions of Miss Ogilvie on this Dolomite region are familiar to tectonic geologists.

But although the results of Lapworth's work have conflicted with some of the grandest geological hypotheses of his time, there is probably no other geologist who employs theory as a working tool to a greater extent in his own research, in teaching, and in prompting investigation and discovery in others, or who so instinctively relies upon the scientific use of the imagination. In his favourite 'fold theory,' 'reciprocal' or 'antilogous' theory of deformation, the rock-fold, made up of two homologous and balanced parts, the one positive and the other negative ('antilogues'), is made to do duty as the archetype, and this type, so characteristic of more or less flexible sheets, is traced in the one direction into the wave-shape of fluids, and in the other direction into the fractures and faults of solid bodies. The fold-line or zero line is identified with the elastic

curve, and the fold-shape is regarded as recognizable in all three dimensions and in all gradations of size. When we hear the applications of this theory employed by Lapworth to account for the land and water hemispheres of the globe, the shapes and trends of all crust movements, and hosts of other geological phenomena, we are fascinated with the manner in which the countless facts fall into apparent order and relationship, and for the time are almost willing to accept his sanguine view that "this twisted plate unlocks the whole treasure-house of the new geology." But we confess, all the same, to a feeling of profound satisfaction when its employer asserts that it must be regarded in the meantime as a working hypothesis, a symbolical expression of facts, rather as a means of grouping than of explaining phenomena, until such time as its assumptions and illustrations have been more fully identified with the every-day results and conclusions of the physicist.

How interesting and stimulating is Lapworth's habit of employing some striking theory and stringing upon it crowds of associated facts, those who attended the Shropshire excursion in 1894 will remember, who heard him describe the effects of the rolling in of the Caledonian crust-creep from the north-west upon the Ordovician region, already folded to the north and south, and how the location of the laccolites and other igneous injections in particular parts of the wrinkles was thus determined; or those who joined the long excursion to Birmingham in 1898, and heard the physiography of the middle valley of the Severn explained as the result of the enforced irruption of the original upper Dee in early Glacial times, or the relations of the Triassic and Palæozoic rock of the Midlands pictured as those of a rugged mountain region slowly buried under a sea of desert-sand and marl. In the same way his advanced students are led to store up and correlate countless facts in their memory by their natural harmony with some all-embracing theory, such, for example, as the explanation of the tectonics, lithology, and palæontology of the Palæozoic rocks on the theory of the developmental history of an ancient festoon island region like that of Eastern Asia, or the explanation of the phenomena of the Carboniferous rocks by the struggle for supremacy between the Caledonian and the Armorican crust-creeps. But these theories are always regarded as servants and not masters, merely provisional approximations to the truth.

3. *Teaching Work.*

For twenty years Lapworth has been sending into the world a stream of geologists, many of them equipped, not only with knowledge of their subject, but with enthusiasm and capacity for original work in it. He has watched the Mason Science College grow into the Mason University College, and that again into the University of Birmingham, and has taken an active part in each step of the advance. While he does not disdain to drill his students and drum into them by question and answer the points he wishes them to get hold of, he is rarely content in his lectures with the mere imparting

of information, but almost invariably he happens upon points which rouse genuine interest. His department not only covers so much of Geology as can be crammed into the limited time allotted to the study, but he has started and maintained large classes in Geography, dwelling particularly on those parts of the study which admit of scientific treatment. Indeed, these classes, the bearing of the Edinburgh address, and the bias of much of his own research, are all symptoms of his attitude towards the sister science, regarding Geology as the Geography of the past, and Geography as the Geology of the present. He has aroused a widespread local interest in Geology by delivering afternoon and evening lectures of a more popular but still systematic character, by holding weekly excursions during the Summer, and by delivering occasional lectures in the neighbouring towns. Amongst the characteristic features of his teaching may be mentioned the classes on structural and field geology, his economic courses, and his research classes. His classes on structural geology learn the principles which guide the field geologist's work, and his practical class spends a term in the actual mapping of a Midland district on the six-inch scale, with the accompanying office-work. One or more workers are generally to be found in the research department engaged upon graptolites, trilobites, brachiopods, rock-specimens, or other material collected in the field. In order that he may have a larger amount of time to devote to investigation and to those portions of his teaching which may be regarded as special to himself, the lovers of science in the city and district have provided him with an assistant-professor to take the rest of his College teaching.

For many years a Geological Section of the Birmingham Natural History and Philosophical Society has met in his rooms in the Mason College. The largest contributor of papers and subjects for discussion has been the Professor himself, but the first drafts of many papers afterwards contributed to the greater learned societies have often been read and discussed by his students in that Section.

By conducting long excursions for the Geologists' Association, the British Association, and other bodies, into districts with which he was especially familiar, by publishing papers and guidebooks descriptive of the regions to be studied, and by his textbooks on geology and physical geography, his teaching has reached a wider circle.

But more far-reaching still has been his influence amongst specialists. The zonal and graptolite work has been taken up by many observers in similar lines of research, not only in Britain, but all over the world, in Scandinavia, Bohemia, France, Canada, and the United States. The value of his advice and assistance has been felt again and again by scientific investigators. His faculty for picking out exceptional facts, the patience which enables him to listen to a long and detailed account of a research, the avidity with which he seizes on those points which fit in with or run counter to his own theories, his delight in each bit of new discovery, and, above all, his encouraging sympathy and the generous manner in which he gives his own ideas and principles in the hope that they

may bear fresh fruit in new soil, all make him an ideal confidant; for to him there is nothing that is "common or unclean," each branch of research has its separate value, and he has the faculty of giving those who consult him the impression that their work forms a part of some greater whole; there is nothing more encouraging to a young man than to find that what he had perhaps considered an isolated line of enquiry is really linked up with the advance of science as a whole.

Although it comes rather under the head of administrative than educative work, it may be here mentioned that Lapworth's intense belief in the practical and educational value of geology has led him to advocate the teaching of the economic side of the science, not only to miners, prospectors, and engineers, but to those engaged in building, surveying, brewing, and sanitary business, and of the pure science to those who are never likely to make any practical use of it except as a means of enlarging their knowledge of nature.

Throughout a good deal of friendly antagonism to the Geological Survey he has always retained the personal friendship of its Officers and strenuously maintained the vital importance of that institution to the country; and acting recently on a Departmental Enquiry into the functions and work of the Survey he has taken his share in remodelling its scope and administration.

4. *Applied Geology.*

During his residence in Birmingham Lapworth has been frequently consulted in matters relating to such subjects as sites, water, and minerals. In this way he has had means of acquiring a vast amount of information, otherwise inaccessible, relating to the structure of the Midland coalfields and their surrounding areas. Indeed, it may be said that one of his main inducements to undertake this class of work has been in order to enrich his knowledge of a branch of science which is practically untouched by the learned societies and the textbooks. The complicated geology of the Midlands, a rugged region covered unconformably by Coal-measures and in most places buried up unconformably by New Red Sandstone, gives rise to a series of difficult problems, each of which must be the subject of a special investigation involving scientific methods, the careful mapping of areas, and the disentangling of the involved structure of difficult districts. In the Midland region, at least, it has become abundantly clear that the most complicated questions of stratigraphy, vulcanicity, and palæontology, all have an eventual, if not an immediate, application to the economic side of the subject; and that there is probably no problem in pure geology that will not in the end have its bearing on applied geology.

In conclusion, one would like, were it permitted, to say a word of the man apart from the geologist. But, after all, is it necessary? His personality is so well known, his influence so wide, his geniality and kindliness of heart so patent to his friends, that it is quite needless to refer to them; and his enemies have yet to be discovered.

Opponents and antagonists there have been in plenty, but it is in their ranks that we find many of those who respect Lapworth most, whilst not a few of them have become his warmest friends.

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II.—A Systematic Nomenclature for Igneous Rocks.

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I. Introductory.

THE present nomenclature of igneous rocks is generally acknowledged to be unsatisfactory, for not only is it without useful meaning, but it is also so unsystematic that it forms a severe tax upon the memory. The manifest and urgent need of reform, which these circumstances create, must be my excuse for presenting in a short note a suggestion likely to require much elaboration. A systematic nomenclature, I need hardly say, can only rest upon a systematic classification, so that the proposals I shall herewith make would have been fitly accompanied by an attempt at producing a classification of the kind. As I have found, however, that much expenditure of time and labour will be necessary to accomplish this task, I have decided upon publishing at once certain proposals with regard to nomenclature, which could be largely applied to classifications at present in use.

It has long been the custom of many authors to name subdivisions of groups by prefixing to the family-name the name of the mineral which distinguishes the subdivision.[1] Thus we have, for instance, *muscovite-granites*, *biotite-granites*, *hornblende-granites*, and *augite-granites*; also *hornblende-biotite-granites*, *augite-biotite-granites*, etc. This system is undoubtedly a step in the right direction, because the name of a sub-group is thus made to point out the distinguishing feature in its composition. When more than one prefix is required, however, such names become too cumbrous for general use, and the practical result is that in such cases a new name is invented, generally signifying nothing but the locality where the rock was first found, or the name of its discoverer. The method breaks down, in fact, under a severe test.

II. Description of Prefixes.

The system of nomenclature which I propose is based upon that just described, but differs from it in that the prefixes are *contracted*. Several can be used, therefore, before a name tends to exceed a reasonable number of syllables in length. Instead of *hornblende-biotite-granite*, for instance, I should say *hornbi-granite*, pronouncing the *bi*-syllable long, as in 'biotite.'

Other advantages have been secured by the use of conventions as to the arrangement of the prefixes, and as to the exact meaning of the family-names. The order of the prefixes denotes the relative abundance of the minerals, that of the most abundant standing next to the family-name. Thus in a *hornbi-granite* biotite preponderates over hornblende, whilst in a *bihorn-granite* the reverse is the case.

[1] I use the term *family* throughout in the sense in which it is used by Rosenbusch in his "Elemente der Gesteinslehre," that is to say, for groups like the *granites*, *diorites*, etc.

If objection were taken to making the relative abundance of minerals a factor in the nomenclature, I should answer that I believe it will prove a useful step, as too little attention has hitherto been paid to variations in the relative abundance of a rock's constituents, and there exists a very simple method of determining this factor.[1]

Other properties besides mineral composition are occasionally made use of as bases of subdivision, and further prefixes will be required in naming the groups thus formed. When the subdivisions are based upon *structure*, prefixes may be obtained by contracting the names of the various structures. For example, *pilotaxitic* can be contracted to *pitaxo-*, *intersertal* to *inserto-*, and so forth. It is almost exclusively amongst the dyke-rocks and lavas that structure is made the basis of subdivision, and names would be produced such as *mipegmo-rhyolite* for a granophyric or micropegmatitic rhyolite, or *hypidio-basalt* for a basalt with hypidiomorphic-granular structure.

Besides mineral and structure prefixes, others denoting some fact in the chemical composition of the rock as a whole may be required. Thus *bas-* or *basi-* would mean *basic*, *ali-* would signify *alkaline*, and so on. These prefixes should generally come immediately before the family-name, and should be separated from it by a hyphen when they are used to name subdivisions of the principal families. Thus the alkaline-syenite family, a group which may be ranked as of equal importance with the normal or calc-alkaline syenites, would be named *alisyenite*; but the name of the basic subdivision of the diorite family, if such a subdivision were made, would be written *basi-diorite* with a hyphen.

III. Index Minerals.

The use of a family-name must evidently in every case imply the presence in the rock to which it is applied of certain essential minerals, which need not therefore be mentioned in the prefix. These I term the *index* minerals of a family, because, being common to all its members, they serve to point out to which family a new specimen belongs. As an example, I may take the family-name *granite*. Every rock so named, whether there be a prefix or not, must contain the minerals quartz and orthoclase in abundance, and these, therefore, are its index minerals. Granites usually, of course, contain other minerals besides, and some or all of them may be mentioned in the prefix. In the same way the index minerals of *gabbro* are obviously plagioclase and monoclinic pyroxene.

It is very important that accurate definitions of the index minerals of all rock-families should be provided; but I am not in a position to supply them at present. A few such definitions I have been successful in framing, and I therefore feel confident that with sufficient study every family can be properly defined.

In the meantime, before this work is completed, the want of accurate definitions will not seriously affect the application of

[1] See A. Rosiwal: Verhandlungen der k. k. geol. Reichs-Anstalt, 1898, p. 143.

the system of nomenclature here proposed. Petrologists of any experience know more or less accurately from constant use the index minerals of every family, and ambiguity is likely to arise only in the case of rocks falling near the boundary between two families.

IV. The Prefixes *a-* and *mono-*.

The recognition of index minerals and the formation of definitions would be of little use, however, if the fact were not acknowledged that rocks exist which do not contain the index minerals of any family, and so cannot be classified at all if the scheme be rigidly maintained. So far as I know, such aberrant forms are nearly always *schlieren*, products of differentiation in immediate continuity with and passing gradually into the parent mass; and they are therefore generally classed along with the rock of their parent mass, from which they differ only in the absence of one of the index constituents.[1] To indicate the abnormality of their composition in their names, I propose to place in the prefix the name of the absent index mineral, preceded by the privative *a-*. This combined prefix should stand immediately in front of all the other mineral prefixes, separated from them by a hyphen. As examples of names thus produced I may quote *apyr-gabbro* for *anorthosite*, which is essentially a gabbro without the pyroxene, and *apyr-magne-peridotite*, which denotes certain of the *schlieren* which sometimes occur in masses of gabbro and peridotite, and consist of magnetite associated with olivine and only traces of other minerals.

The difficulty of determining whether a mineral is actually present or not, when it is suspected in small quantities, will tend to produce confusion, if an index mineral must necessarily be absolutely wanting before it can be declared absent in the name. For all practical purposes an index mineral has vanished if its proportion be less than 5 per cent. by weight of the whole rock, and I therefore propose this amount as the limit, falling below which the rock either passes into another family or requires the missing index mineral placed in the prefix with the privative *a-*.

There remains yet one more prefix whose use I have found indispensable, namely *mono-* or *mon-*, meaning *only*. It is of use chiefly in the case of sub-groups which are distinguished from others of the same family by the *absence* of minerals, rather than their presence. For instance, a rock which consists of nothing but the index minerals of some family can only be distinguished from other members of the same family by the absence of the minerals which characterise them. This want of additional minerals may be expressed by using *mono-* as the sole prefix in naming a rock. Thus a *mono-gabbro* is a rock consisting solely of an intermediate or basic plagioclase and a monoclinic pyroxene, the index minerals

[1] The word *schliere* is here used in the sense defined by Rosenbusch ("Elemente der Gesteinslehre," 1898, p. 41), Reyer ("Theoretische Geologie," p. 81), and Zirkel ("Petrographie," 1893, i, p. 787). It has been introduced into the English language by Holland ("The Charnockite Series": Mem. Geol. Surv. India, vol. xxviii, p. 217).

of the gabbro family, no account being taken of the usual accessories. Reference to the table (No. IV) on p. 312 will show that this prefix occurs again in the descriptive name for *umptekite*, namely *monamph--alisyenite*. It is used here because, whilst in certain members of the family an amphibole is the most abundant ferromagnesian mineral, in *umptekite* it is the *only* one, and to avoid all risk of confusion it is well to state that fact in the name. The use of this prefix is really simply a means of avoiding the use of the same name in both an extended and restricted sense at once.

V. Order of Prefixes.

The order in which prefixes of different kinds are placed when required in the same name is an important matter. The rule which I propose is that a prefix used to name a major subdivision be always placed nearer to the family name than a prefix used for a minor subdivision. For instance, supposing that the subdivisions of the dolerite family, founded on mineral composition in the ordinary way, were themselves subdivided according to structure, then the structure prefix would always precede the mineral prefix in the name of each of the ultimate subdivisions, producing such names as *ophit-oli-dolerite*, *hypidio-horn-dolerite*, etc. When on the other hand the first subdivision is on the basis of structure, as in the rhyolites, the order must be reversed, producing such names as *diopsi-mipegmo-rhyolite*, *bi-perlo-rhyolite*, etc. This rule is obviously the most convenient, for it leaves the name of a major subdivision intact in the names of the minor subdivisions which it contains, so that a single glance shows to which major subdivision any minor subdivision belongs. It must not be supposed that this double subdivision and the cumbrous names it produces will be frequently employed. It is probable, however, that as the study of igneous rocks progresses, subdivision will be carried further and further; and it is therefore well to be prepared beforehand with a method for naming sub-groups of future origin in any system of nomenclature which we adopt to-day.

It will have been observed that hyphens are always placed between prefixes of different kinds, and between a prefix and the family-name, in order to facilitate reading the compound name. They are not required to separate prefixes of the same kind, as for instance when a series of mineral prefixes follow one another, nor should they be inserted within family- or subfamily-names.

VI. Lists of Contractions.

The various kinds of prefixes have now been fully discussed. For the sake of uniformity, in case others should wish to use this system, I proceed to display in full all the contractions which appear likely to be necessary. The first list, containing the contractions of mineral names, includes, I believe, all that are likely to be required. It will be noticed that different forms are generally needed according to whether the next syllable begins with a vowel or a consonant.

Table I. List of Contractions for the Names of Minerals.

Mineral	Before a Consonant	Before a Vowel
Actinolite	Actino-	Actin-
Ægyrine	Ægi-	Æg-
Albite	Albi-	Alb-
Amphibole	Amphi-	Amph-
Analcime	Analci-	Anal-
Andesine	Ande-	Andes-
Anorthite	Anorthi-	Anorthi-
Anorthoclase	Anorthoclase-	Anorthoclas-
Anthophyllite	Antho-	Anthy-
Apatite	Apa-	Ap-
Arfvedsonite	Arfve-	Arfved-
Augite	Augi-	Aug-
Barkevicite	Barke-	Bark-
Basalt Hornblende	Bashorn-	Bashorn-
Biotite	Bi-	Bi-
Bronzite	Bronzi-	Bronz-
Bytownite	Byto-	Byt-
Cancrinite	Cancri-	Can-
Corundum	Corun-	Corund-
Diallage	Dial-	Dial-
Diopside	Diopsi-	Diop-
Enstatite	Ensta-	Enst-
Felspar	Fels-	Fels-
Garnet	Garnet-	Garnet-
Haüyne	Hau-	Hau-
Hornblende	Horn-	Horn-
Hypersthene	Hyper-	Hyper-
Labradorite	Labra-	Lab-
Leucite	Leu-	Leuc-
Magnetite	Magne-	Mag-
Melanite	Melano-	Melan-
Melilite	Melli-	Mel-
Mica	Mica-	Mica-
Microcline	Microcline-(Ortho-)	Microcline-(Orth-)
Muscovite	Musc-	Musc-
Nepheline	Neph-	Neph-
Nosean	Nose-	Nos-
Oligoclase	Oligo-	Olig-
Olivine	Oli-	Oliv-
Orthoclase	Ortho-	Orth-
Pyroxene	Pyro-	Pyr-
Quartz	Quartz-	Quartz-
Riebeckite	Riebe-	Rieb-
Sodalite	Sodali-	Sodal-
Sphene	Spheni-	Sphen-
Titanite	Tita-	Titan-
Topaz	Topa-	Topaz-
Tourmaline	Tourma-	Tourm-
Tremolite	Tremo-	Trem-
Zircon	Zircon-	Zirc-

The names of structures do not admit of contraction quite so readily as those of minerals, but it is only in very few cases that the name cannot be reduced to three syllables. The list of contractions given below (Table II) is almost complete, but for some words such as *hypocrystalline-porphyritic* and *glomeroporphyritic*, besides *granular*, *granulitic*, etc., unambiguous contractions do not exist. It may become necessary, in some cases, to adopt new names for such structures, though I hesitate to go so far at present. Suggestions from any quarter will, however, be gratefully received and considered. In the case of names for which contractions cannot be invented, and which are therefore omitted from the following list, it will probably be best for the present to use the whole name without contraction.

The contractions are given in the form which should be used when the next syllable begins with a consonant. When followed by a vowel the final *-o* should in most cases be dropped. The pronunciation remains unaltered in contractions which are formed by the omission of a syllable from the centre of the word. Thus, for instance, the *mi-* in *misphero-* is pronounced long as in 'microscope' or 'microspherulitic,' and *not* short as in 'miss.'

The name *amygdaloidal* is omitted from the list because that structure is merely a secondary derivative of the vesicular structure. As it is generally the rule in naming an igneous rock to imagine it back in its original and unaltered condition, the two structures

become for our purpose essentially the same, and the name *vesicular* may be used for both.

Table II. List of Contractions for Names of Structures.

Name	Contraction	Name	Contraction
Allotriomorphic-granular	Allotrio-	Ophitic	Ophito-
Eutaxitic	Eutaxo-	Panidiomorphic-granular	Panidio-
Felsophyric (see Microfelsitic)	Mifelso-	Pilotaxitic	Pitaxo-
Glassy or vitreous	Vitri-	Pœcilitic	Pœcilo-
Hyalopilitic	Hyapilo-	Porphyritic	Porpho-
Hypidiomorphic-granular	Hypidio-	Rhomboidal (Rhomben-felspar structure)	Rhomfels-
Intersertal	Inserto-	Spherulitic	Sphero-
Miarolitic	Miaro-	Trachytic	Tracho-
Microfelsitic	Mifelso-	Variolitic	Varilo-
Micropegmatitic or Granophyric	Mipegmo-	Vesicular	Vesico-
Microspherulitic	Mispheroo-	Vitrophyric (see Glassy)	Vitri-
Ocellar	Ocello-		

There remain a few miscellaneous contractions which are occasionally employed, and may be conveniently exhibited in another table. The prefixes for 'rich in soda' and 'rich in potash' are obtained by contracting the German words *natron* and *kali*, rather than the English words *soda* and *potash*, because, owing to their use for symbols in chemistry, the former are more widely understood in England than are the latter in Germany.

Table III. List of Miscellaneous Contractions.

Before a Consonant	Before a Vowel	Meaning
a-	an-	without (privative)
ali-	ali-	rich in alkalies
basi-	bas-	basic
calci-	calc-	rich in lime
kali-	kali-	rich in potash
kalko-	kalk-	rich in lime (German)
medio-	medi-	medium, middle
mono-	mon-	only
multi-	mult-	much, many
natro-	natr-	rich in soda
pauci-	pauc-	little, few

VII. Family-Names.

For the sake of further illustration, I have prepared, and reproduced below, a table showing the classification of the Alkaline Series of plutonic igneous rocks, which gives both the old and the new names (see Table IV, p. 312). The Alkaline Series is troubled with a particular superabundance of names. Probably this is because most of its members have been discovered in recent years, since detailed petrographical research became general, and its families have therefore actually become subdivided to a far greater extent than those of the Calc-alkaline Series, although the latter has been studied very much longer. The table therefore shows that a great number of names will become redundant, if a systematic nomenclature be adopted.

Hitherto nothing has been said respecting the names of families. This is because complete revolution is impossible, and existing

names must be accepted to a great extent, however meaningless and awkward they may be. There is, however, one family-name which I have felt the necessity of altering, as reference to the table will show; that is, the name *nepheline-* or *elæolite-syenite.* The name was probably the best which could be given at the time the family was established, pointing out as it did the relation which these rocks were then supposed to hold to a well-known group, the Syenites.[1] In view of what we know at the present time, however, concerning the Alkaline Series, the name is not only useless but misleading. In no essential quality does the so-called nepheline-syenite resemble a normal syenite. The silica percentage, which ranges, roughly speaking, from 50 to 60, is that of the more basic diorites and some acid gabbros, rather than that of the syenites. As regards mineral composition also, the two are absolutely distinct. The normal syenite consists of orthoclase and a ferromagnesian mineral, which are the index minerals of the family, together with a plagioclase felspar not exceeding the orthoclase in amount, and usually a small quantity of quartz. The nepheline-syenite, on the other hand, contains alkali-felspar (either potash or soda predominating) and nepheline as index minerals, with which are associated ferromagnesian minerals in small quantity and mostly of an alkaline type, and frequently sodalite, leucite, nosean, cancrinite, etc., without plagioclase or quartz. Hence it is evident that merely removing the nepheline from a nepheline-syenite would not make it into an ordinary syenite, and the name has therefore no justification. Since the family is a member of the Alkaline Series, and at the same time occupies a middle place in the range of silica percentage, I propose to substitute for *nepheline-syenite* the descriptive name *midalkalite.* This is compounded of 'mid,' the abbreviated form of 'middle,' and 'alkali,' which signifies the series to which the family belongs. The only alternative was the form *medalkalite,* adopting the Latin word *medius* for 'middle.' The word sounds strange and uncouth, however, to English ears, and conveys its meaning much less clearly than *midalkalite*; whilst the latter is probably equally adaptable to French and German.

Possibly the coining of a new name upon a new principle demands some apology. It may be suggested that the better course would have been to select one of the numerous names already given to various members of the nepheline-syenite family, and to extend its meaning to embrace the whole group. Every other family-name has arisen in that way, and a uniform system might have been preserved. I consider, however, that there are very strong objections to any such extension of the meaning of a name; indeed, I hold that an extension of meaning is justifiable *only when the additional species taken in do not surpass, either in the wideness of their difference from one another or in number, the species already associated with the name* —the word *species* being here used merely to designate any small

[1] The name was given by Rosenbusch in 1877. He himself anticipates the objection which I am about to raise (see Mik. Phys., 1877, ii, p. 204), and proposes that, if it be insisted on, the name *foyaite* should be adopted instead.

group possessing well-recognised characteristics. It is inevitable that the meaning of a name should be altered from time to time—sometimes narrowed, though generally extended; but every such alteration must be gradual, taking place step by step. The reason for this lies in human nature. A radical alteration in the meaning of a name involves such a revolution of ideas and habits that most men refuse to accept any such proposal; and its adoption by only a few simply leads to endless confusion. On the other hand, a slight alteration of meaning requires but a trifling readjustment of ideas and habits; and, therefore, so long as the change is clearly justified, it is soon recognised as convenient and gradually comes into use.

Whilst these objections clearly prevent the adoption of such names as *lujaurite*, *litchfieldite*, etc., to replace *nepheline-syenite*, there is one name, *foyaite*, which would appear at first sight to escape them. It has been suggested, and sometimes used, as a synonym for *nepheline-syenite*, and few authors, if any, now restrict its meaning solely to the type of rock originally described by Blum under that name. A little investigation shows, however, that even this name has not had an application wide enough to allow of its extension over the whole group which I propose to call *midalkalites*. Rosenbusch uses it to include only what might be called the normal types of nepheline-syenite; those which are poor in coloured constituents, and in which the alkali felspars are both abundant, the potash felspar predominating over the soda felspar, rather than the reverse. This use of it excludes such types as Litchfieldite, Laurdalite, Lujaurite, and many others, but includes Brögger's and Derby's Foyaites. At the same time it appears probable that the majority, if not all, of those authors who have used *foyaite* as synonymous with *nepheline-syenite*, have had in their minds only those normal types included by Rosenbusch under that name. The name is therefore applied to a definite group of rocks closely allied to one another, and it would be a contravention of the principle above stated to apply it to such widely differing rocks as *laurdalite*, *litchfieldite*, *borolanite*, *leucite-syenite*, and *sodalite-syenite*. It will, indeed, be found convenient to retain the name *foyaite* with Rosenbusch's meaning as marking a subfamily.

The only course left me was to coin a new name. A descriptive name seemed likely to be most convenient, and I therefore chose *midalkalite*. The fact that all other family-names are of the non-descriptive kind, and that I do not at the same time propose descriptive names to replace them, is no valid objection to the introduction of one such name. If this one prove a success, others can be added from time to time as desired.

Two other family-names require a brief notice. Desiring to reduce the number of existing family-names as far as possible, I have followed Rosenbusch and grouped together the soda and potash rocks, so that the theralites and shonkinites form one family, and the ijolites and missourites another. Instead of retaining the double name for each family, however, as he does, I have selected one of the names in each case to cover both the soda and potash

rocks. Guided by the principle above set forth, I have selected the name of the soda rocks in each case, because they are far more important, both in number and variety, than the corresponding potash rocks. The family of *Theralites and Shonkinites* therefore becomes the family of *Theralites*, and the family of *Ijolites and Missourites* becomes the family of *Ijolites*. The name *ijolite* is neither convenient nor euphonious, but I fear there exists no alternative which could be adopted. It is not objectionable enough to warrant the proposal of a new name, and there is no other name in the family which has sufficient extension to allow it to be applied to the whole family in accordance with the above-mentioned rule.

The chief reason for combining the soda and potash rocks in one family as I have done, is that if they were separated here, amongst the plutonic alkaline rocks, the same multiplication of families ought to be allowed throughout the whole igneous series. Instead of about thirty-five families, as we now have, we should then have nearly sixty, each with a name to be remembered. This seems to me too large a number, in the present state of our science. It will be observed, however, that I propose still to keep the potash and soda rocks separated, making them subfamilies instead of families, and naming them accordingly. The theralites and shonkinites, for instance, become respectively *natrotheralites* and *kalitheralites*.

The silica percentages, which are stated for each family in Table IV, are intended for information only. They show roughly the limits of silica variation in each family, so far as its members have been analysed and the results have been accessible to me, but they must not be considered as a part of its definition. The limits are stated in whole numbers for the sake of clearness, but they should be read so that the limit stands 0·5 per cent. on the *outside* of the figure given. A range of 67–57 per cent., for example, must be read as 67·5–56·5 per cent. This convention is necessary because the limiting values fall more frequently on the half unit than the unit.

Table IV. Scheme of Classification of the Plutonic Division of the Alkaline Series of Igneous Rocks.

Family I.—ALIGRANITES. (= Alkaligranites, Ros.)

Two Index Minerals: Quartz; *and an* alkali-felspar.
SiO_2 % 78–68.

1. Bi-aligranite (= Nordmarkite, Brögger, *in part*).
2. Amph-aligranite (*includes* Riebeckite-granite, Sauer).
3. Pyr-aligranite.

Family II.—ALISYENITES. (= Alkalisyenites, Ros.)

One Index Mineral: *An* alkali-felspar.
SiO_2 % 67–57.

1. Pyrobiamph-alisyenite (= Pulaskite).
2. Biamph-alisyenite (= Nordmarkite, *the greater part*).
3. Monamph-alisyenite (= Umptekite).
4. Rhomfels-pyr-alisyenite (= Laurvikite).
5. Æg-alisyenite (= Ægyrine-syenite).

Family III.—MIDALKALITES. (=Nepheline- *or* Elæolite-syenites.)

Two Index Minerals: *An* alkali-felspar; *and* nepheline.
Si O_2 % 60–48.

1. Pyr-midalkalite (= Foyaite, Blum; Pyroxene-foyaite, Ros.).
2. Amphi-midalkalite (= Amphibole-foyaite, Ros.).
3. Bi-midalkalite (= Mica-foyaite, Ros.; *includes* Miascite; *and* Ditroite).
4. Natro-midalkalite (= Litchfieldite).
5. Rhomfels-pyr-midalkalite (= Laurdalite).
6. Eudægi-midalkalite (= Lujaurite).
7. Leuci-midalkalite (*includes* Leucite-syenite *of Magnet Cove, Arkansas*).
8. Cancri-midalkalite (= Cancrinite-syenite).
9. Melano-midalkalite (*includes* Borolanite; *and* nepheline-syenites *of Montreal and Magnet Cove, Ark.* [Cove-type]).
10. Sodali-midalkalite (*includes* Sodalite-syenite *of Julianehaab*).

Family IV.—ESSEXITES.

Three Index Minerals: Labradorite; augite *or* diopside; *and* biotite (*or an* alkaline amphibole *or* pyroxene).
Si O_2 % 50–43.

1. Multifels-essexite (*includes* Essexites *of Cabo Frio; Jacupiranguinha; Rongstock; and Dignaes*).
2. Mediofels-essexite (*includes* Essexites *of Salem, Mass.; and Sölvsberg*).
3. Paucifels-essexite (*includes* Essexites *of Arkansas; Montreal; Penikkavaara, near Kuusamo; and Brandberg*).

Family V.—THERALITES. (= Theralites *and* Shonkinites.)

Three Index Minerals: *A* pyroxene; felspar (plagioclase *or* orthoclase); *and* nepheline, *or* sodalite, *or* leucite.
Si O_2 % 50–40.

Subfamily A.—NATROTHERALITES.

1. Augi-natrotheralite[1] (= Theralite, *sen. str.*; *and includes most of the* Teschenites).
2. Ægi-natrotheralite (= Natronsussexite).
3. Barke-natrotheralite (= *certain* Teschenites).

Subfamily B.—KALITHERALITES.

1. Augi-kalitheralite[1] (= Shonkinite).
2. Ægaugi-kalitheralite (= Pyroxene-malignite).
3. Amphi-kalitheralite (= Amphibole-malignite).
4. Melano-kalitheralite (= Garnet-malignite).

[1] The *a* of *natro-* and of *kali-* is pronounced long as in 'state.' The *i* of *kali-* is short as in 'pit,' but it is dropped in the name *kalijolite*, in which the first *i* should be pronounced long as in 'write.'

Family VI.—IJOLITES. (= Ijolites *and* Missourites.)

Two Index Minerals: Pyroxene; *and* nepheline, *or* sodalite, *or* leucite.
SiO_2 % 47–40.

Subfamily A.—NATRIJOLITES.

1. Augi-natrijolite[1] (*includes* Ijolites *of Imandra See, Kola Penin.*; Elæolite-syenite (Ridge-type) *of Magnet Cove*; *and* Jacupirangite).
2. Ægaugi-natrijolite (*includes* Ijolites *of Kuusamo*; *Kaljokthal*; *and Alnö*).
3. Ægi-natrijolite (= Urtite).
4. Aneph-sodali-natrijolite (*includes* Tawite; *and* Sodalite-syenite *of Square Butte, Montana*).

Subfamily B.—KALIJOLITES.[1]

(*Includes at present only* Missourite.)

VIII. Changes in the Subdivision of Families.

The subdivisions of the families contained in the above table are in almost every case those suggested by Rosenbusch in the most recent editions of his works, but I have not adopted them without testing their validity whenever possible.[2] The aligranites he does not subdivide, but as I see no reason why they should not be treated in the same way as the granites, I have subdivided the family on the basis of its coloured minerals. Amongst the midalkalites, the subdivision *melano-midalkalite* is new. Rosenbusch places borolanite in the leuci-midalkalite (leucite-syenite) group; but, considering that Horne and Teall distinctly state that they give that name to a rock consisting essentially of orthoclase and melanite, and that leucite only occurs in parts of the mass which they describe, I think that borolanite and rocks of that composition should be entitled to rank as a distinct sub-group in the great midalkalite family. Garnet plays an important rôle as an original constituent in many basic rocks of the alkaline series; to a much greater extent indeed than is generally recognised.

The two rocks *urtite* and *tawite* are removed from the midalkalite (nepheline-syenite) family, with which they are classed by Rosenbusch, presumably because of their association. They will be found in the family to which their mineral composition assigns them, that is to say, the Ijolites.

The principal difficulty which I experienced in naming subdivisions was the frequent want of definite information as to the relative proportions of the constituents of a rock. Many descriptions even of recent date fail in this respect, and it would be well if all petrologists realized, as a few already do, that a mere statement of the minerals found in a rock is not a complete description of it. On

[1] See footnote on preceding page.
[2] See "Elemente der Gesteinslehre," 1898, and Mikr. Phys., 1896, vol. ii.

the contrary, it is the relative proportions of the constituents which establishes the identity of the rock. For instance, a kalitheralite (e.g. malignite) may contain the same minerals as an alisyenite. The former may contain 25 per cent. orthoclase, 25 per cent. nepheline, and 50 per cent. of ferromagnesian minerals, and the latter 90 per cent. orthoclase, 5 per cent. nepheline, and but 5 per cent. of ferromagnesian minerals. They may be composed of exactly the same minerals, and yet in such different proportions that they belong to widely separated families.

Another example will show how unsatisfactory is this practice of merely giving a qualitative description of a rock. I have, of late, frequently had to read descriptions of rocks in order to determine to which subdivision of a family they should be consigned in cases where the subdivisions are distinguished by the most abundant ferromagnesian mineral. In one description, after two or three pages had been devoted to an amphibole and two pyroxenes which the rock contained, it was just mentioned at the end that the rock contained biotite. The impression given was that the amphibole and pyroxenes were the important ferromagnesian minerals, whilst biotite was quite subordinate in quantity. On examining a slice of the rock, however, I saw at a glance that the biotite was far more abundant than both the amphiboles and pyroxenes taken together, and that it had received so little attention merely because it presented no point of special interest. Now that an easy method of determining the relative proportions of constituents is known, namely, that of Rosiwal already referred to (see footnote, p. 305), it is to be hoped that there will be speedy reform in this matter.

Although I believe that the names given to the rocks in the above table generally represent their composition correctly, I cannot vouch for the fact. Owing to the vagueness of many descriptions in the above-mentioned respect, and because I have not thought it worth while merely for the purpose of illustration in a preliminary notice to spend much time in consulting literature not to be obtained in Cambridge, it may be that a few of my names will bear correction. That cannot, however, affect the value of the system of nomenclature itself; and I trust that authors who are acquainted with any rocks which I may have misnamed will be so kind as to set me right.

IX. The Naming of Newly Discovered Rocks.

In conclusion, I may perhaps offer some suggestions as to how newly discovered rock-species should be named in the future. The first step in identifying a rock is to determine its essential constituents, that is to say, those which make up more than 5 per cent. by weight of the whole rock. According to their nature, whether they are of the alkaline type or not, the rock is first assigned either to the Alkaline or the Calc-alkaline Series. Amongst the essential constituents it will next usually be possible to find two or three which coincide with the index minerals of some particular family, and the rock can then be forthwith placed in that family. Should the essential constituents include the index

minerals of more than one family, which will rarely be the case, the rule is to choose those which are most abundant. The family-name being thus obtained, observe next upon what basis the family is subdivided, whether it is by the nature of the ferromagnesian mineral, by the kind or quantity of felspar present, or by some other property. All the constituents of the rock, essential and accessory, being now considered, it will be easy to assign the rock to its right subdivision, supposing one already exists. If, on the other hand, the rock is a new type and no place awaits it, a new subdivision can be created and named in accordance with the general system.

The only rocks which it will be found difficult to name are those which do not contain the index minerals of *any* family. In such cases the association of the rock is the first point to be considered. If any such rock clearly forms part of an igneous mass which can be readily assigned to a family, let the doubtful rock also be assigned to the same family, and give it a name in which the missing index mineral is preceded by the privative *a*-. If, however, besides being entirely new, the rock does not appear to be associated with any known type, it becomes a question whether a new family should be established. This course must be adopted only when there is really no other way of naming the rock, and the family name selected should be, as far as possible, descriptive of the rock's peculiarity in mineral or chemical composition.

I cannot end without expressing my gratitude to Prof. Bonney, my first master, for the interest with which he has followed my work upon classification and nomenclature and for the many suggestions which he has freely offered. To Prof. Rosenbusch also I am deeply indebted for the kindly instruction received at Heidelberg, which has opened my eyes and smoothed my path in many ways, but more especially in this research.

III.—Notes on the Tourmaline of the White Granite of Meldon, Dartmoor.

By Lieutenant-General C. A. McMahon, F.R.S.

THIS "remarkable variety of granite" was briefly described by Mr. J. J. Harris Teall, F.R.S., in his "British Petrography" (1888), p. 316, and an interesting account was given in a footnote of the process by which the author was able to identify the topaz found in the rock.

In a paper on Dartmoor published in 1893 (Q.J.G.S., vol. xlix, p. 385), I described in some detail the mode of occurrence of this intrusive rock and some of its characteristics; and in the following year (Q.J.G.S., vol. L, p. 338) I noted the occurrence of a second outcrop on the flank of South Down.

None of the above references to the white granite of Meldon contain a description of the tourmaline found in it, and as this mineral presents some unusual features a few remarks on it may interest students of petrology.

White tourmaline (achroite) has not yet, so far as I am aware, been found in the British Islands, but the tourmaline of the Meldon granite approximates to colourless tourmaline sufficiently closely to render it probable that if the attention of mineralogists is drawn to the subject true achroite may yet be detected in British rocks.

The following remarks are based on the study of a good suite of thin slices made from hand specimens collected by me, and of numerous fragments of tourmaline separated from these specimens with the aid of a heavy solution. When I was at Meldon the granite was being quarried, and I was able to get unweathered samples.

Fragments of tourmaline examined with a powerful pocket lens are seen to be in part colourless and in part of pale-brown colour.

Under the microscope, when examined with the aid of transmitted light, the tourmaline in thin slices (as thin as those "made in Germany" for instance) is absolutely colourless and devoid of dichroism. It is consequently difficult to distinguish from the topaz with which it is associated. This difficulty is increased by the fact that both minerals, as seen in thin slices of the Meldon rock, closely resemble each other in habit. Both are allotriomorphic and occur in irregular shaped grains. The tourmaline rarely presents itself in prismatic form, whilst the cleavage, usually so characteristic of topaz, is rarely to be seen in the topaz of the Meldon granite. As, moreover, the refraction of both minerals is higher than that of Canada balsam, and of the felspar and quartz with which they come in contact, the difference in the refraction of topaz, as compared with that of tourmaline, does not help one to discriminate between them.

The positive character of the double refraction of topaz could not be made out in any of my slices, as no bisectrix could be seen in converging polarized light. The axial angle in topaz from different localities varies very much, and it is probably large in the variety found in the Meldon granite.

The rock under consideration affords an illustration of the help that may sometimes be afforded by our much abused thick slices of English manufacture. In such slices the Meldon tourmaline presents a somewhat more normal appearance. Even in thickish slices, however, the mineral is sometimes colourless in whole or in part, but more often a reddish or reddish-brown streak or patch is to be seen in the otherwise colourless grains which exhibits the characteristic dichroism of tourmaline.

The appearance of these coloured stripes and patches suggests to me the possibility that the colour may be due to the alteration of an originally colourless tourmaline; namely, to the oxidation of the iron contained in the mineral. Iron is not an essential constituent in this complex silicate, and my previous studies have familiarized me with the idea that iron may be removed, or oxidized, without breaking up the fundamental silicate of which it is more or less a casual unessential member.

The tourmaline in the Meldon granite very rarely exhibits prismatic outlines in thin slices, but in the isolated fragments both

this mineral and the topaz show a slightly increased tendency to do so. The tourmaline, however, even in thin slices, is frequently elongated in the direction of the vertical axis (c'); and as the greatest absorption takes place at right angles, and compensation with the quartz wedge occurs parallel to this direction (viz. to c'), a ready and sure means of identifying the mineral exists in such cases.

When this observation can be made one cannot remain in doubt as to which is tourmaline and which is topaz, as the latter is not dichroic in thin slices, and compensation with the quartz wedge, in the case of topaz takes place at right angles to c', and in the case of tourmaline parallel to c'.

When dichroism is apparent in the Meldon tourmaline the change is from colourless (e) to a yellowish or reddish-brown (o).

In cases where the above-mentioned observation cannot be made, namely, when dichroism is absent, I have found the following methods very useful.[1]

I have often, when examining the topaz in my slides, been able to obtain in converging polarized light the interference figure of an optic axis, namely, a single bar, or a bar bisecting the first ring of the interference figure, which remained without change of character during a revolution of the crossed nicols through 360°. When this interference figure is obtained it shows clearly that the mineral is a biaxial one, and consequently that it is topaz and not tourmaline. Axial sections of the latter mineral, on the other hand, may be obtained in my thin slices, which in converging polarized light yield a negative uniaxial cross which does not open out on revolving the nicols. Sometimes when the section has not been cut quite normal to the vertical axis of the crystal, only two of the arms of the cross can be seen, and sometimes their point of junction is outside the field. In such cases, with one of Swift's improved one-sixth objectives, I can generally get the two arms just on or just outside the edge of the field, and can make sure that the arms are those of an uniaxial mineral. In cases of doubt I am able to confirm this observation by inserting the one-fourth undulation mica plate, when the double refraction of tourmaline being negative, *one* dot (only half of the cross being visible) appears in a line with the axis of the mica plate and well within view.

Observation of the strength of the double refraction also affords, in some cases, a method of distinguishing between the two minerals. The birefringence of topaz does not exceed 0·010, whilst that of tourmaline is 0·020. The colour of the former mineral, as seen in thin slices, does not rise above the indigo-blue of the second order of Newton's scale, and very often falls below that. On the other hand, the colour shown by the tourmaline in my sections frequently rises to the indigo-blue of the third order.

Lastly, the character of the metamorphism effected by aqueous agents affords a useful test. Tourmaline alters to steatite, mica,

[1] I confine myself to optical tests and those which can be applied to thin slices.

chlorite, and *cookeite*;[1] whilst topaz changes to steatite, mica, and *kaolin*.

In my Meldon specimens the green tint seen in some of the tourmaline is probably due to the birth of ultra-microscopic particles of chlorite in the originally colourless crystals. The topaz, on the other hand, sometimes exhibits partial kaolinization, and when it does so it is clear that the mineral is topaz and not tourmaline.

On the whole, I think it probable that the somewhat partial and patchy colour seen in the Meldon tourmaline is due to the post-genital alteration of an originally colourless variety of this mineral. I do not think the faint colour now visible is due to the bleaching of an originally dark-coloured tourmaline. An operation of this kind would imply the bleaching of the whole of the white granite itself, which I do not think probable. Moreover, it would involve chemical action to an extent that must have left very powerful marks on the felspars and other susceptible minerals contained in the rock, that could not remain unobserved.

IV.—An Abnormal Section of Chloritic Marl at Mupe Bay, Dorset.

By A. Strahan, M.A., F.G.S.

IN "The Geology of the Isle of Purbeck and Weymouth" (p. 152) I referred to some green sand which occurs next below the Chalk in Mupe Bay, Dorset, as somewhat resembling Chloritic Marl, but as being too thick for that bed. As it was followed by the Gault, I concluded that it belonged to the Upper Greensand. The section was subsequently visited by Mr. W. Hill, who collected from the sand in question *Holaster subglobosus*, var. *altus*, and *Echinoconus castanea* among other fossils, and inferred that it was Chloritic Marl. He considered that though it passed up insensibly into the Chalk it was faulted against the Gault, but that there had been also considerable contemporaneous erosion of the Upper Greensand. In April of this year I revisited the section in company with Mr. Hill, and was fully satisfied as to the correctness of his views. The following account has been drawn up from our observations:—

The Lower Chalk becomes extremely impure in its lower part, and contains much glauconite; it thus graduates insensibly downwards into a gritty glauconitic sand. The sand contains a few phosphatic casts, more or less worn or corroded, scattered throughout it, but has a well-marked nodule-bed crowded with these casts at its base; other fossils with the shell preserved and not filled in with phosphate occur also throughout the whole bed.

Below the sand comes a sandy glauconitic clay, forming part of the Gault, but the fact that the separation is sharp, and that the chert-beds of the Upper Greensand and the passage-beds down into the Gault are absent, proves that the two are faulted together, although the fault-plane is parallel to the highly inclined bedding.

[1] See Dana's textbook, last edition.

The thickness of sand between the fault and what may be taken as the base of the Chalk amounts to 15 feet.

The following list of fossils includes those collected in April, 1901, and those obtained previously by Mr. Hill. They prove that the whole of the sand should be referred to the Chloritic Marl. The identifications are by Mr. E. T. Newton.

CHLORITIC MARL, MUPE BAY.

Scattered through the Bed.

Terebratula squamosa, Mant.
Cidaris Bowerbanki, Forbes.
Echinoconus castanea, Brongn.
Holaster subglobosa, Leske.
Holaster subglobosa, var. *altus*, Ag.
Holaster suborbicularis? Defr.
Plocoscyphia?

From Nodule-bed at base.

Helicoceras, sp.
Columbellina?
Turritella, sp.
Cucullæa carinata? Sow.
Cucullæa mailleana? D'Orb.
Isocardia, sp.
Trigonia, sp.
Cardium, sp.
Cardita, sp. (? *tenuicosta*).
Pleuromya (*Panopæa*).
Cytherea plana, Sow.
Plicatula, sp.
Exogyra, sp.
Polyzoon on Lamellibranch.
Rhynchonella (near to *grasiana*).

A section at the top of the cliff (referred to on p. 151 of the Memoir on the Isle of Purbeck) shows that the Chloritic Marl maintains an abnormal thickness for 200 yards at least west of the section on the beach. It is there succeeded downwards by a considerable thickness of Upper Greensand, in which, however, no representative of the Chert Beds could be found, and which presumably belongs to the lower part of the formation. Two explanations for this sequence may be offered: firstly, that the fault which throws Chloritic Marl against Gault on the beach does not follow the bedding precisely, but cuts obliquely through the Upper Greensand, so as to throw Chloritic Marl against that formation westwards; secondly, that the upper part of the Upper Greensand suffered erosion before the deposition of the Chloritic Marl.

The first explanation is supported by the fact that the section on the beach places the existence of a fault beyond doubt, and shows also that the fault is approximately parallel to the highly inclined beds. In favour of the second explanation it may be urged that the abnormal thickness and character of the Chloritic Marl point to the Upper Greensand having undergone erosion. The phosphatic casts of fossils, though but little water-worn, are fragmentary. While, therefore, they have neither travelled far nor been rolled upon a beach, they are not in their original matrix. The absence of any fragments of chert among the nodules in the Chloritic Marl appeared to me to point to the erosion of the Upper Greensand having been but slight, but in explanation of this Mr. Hill suggests that the chert-nodules were formed at a later date, and that the beds were all soft when the erosion took place. For myself I am inclined to think that the segregation of nodules followed as a rule closely upon the deposition of the sediments in which they occur.

The fossils, generally speaking, have too wide a range to determine exact horizons in the Upper Greensand, but Mr. Jukes-Browne points out to me that *Cytherea plana*, which occurs as a phosphatic cast in the nodule-bed, favours the idea of erosion to below the Chert Beds, for he has not observed it from any higher horizon.

In the Memoir on the Isle of Purbeck (pp. 161, 162) I referred to the general consensus of opinion that there had been some slight erosion of the Upper Greensand before the deposition of the Chloritic Marl, and gave some instances, but I know of no other case in which the evidence is so strong or where the erosion appears to have been so great as at Mupe Bay. That it was strictly local is proved by the fact that in Lulworth Cove to the west, and in Warbarrow Bay to the east, the sequence is normal, and the Chloritic Marl resumes its normal thickness of 3 to 4 feet. It is unfortunate that the existence of a fault introduces a doubt how far the incompleteness of the sequence should be attributed to contemporaneous erosion and how far to subsequent movement. While accepting the evidence that there was erosion, perhaps considerable, of the Upper Greensand, I am disposed to call in the aid of the fault at the top as well as at the bottom of the cliff, to account for some of the missing beds.

My thanks are due to Mr. Hill for giving me the opportunity of making this correction, and for supplying much of the material on which it is founded.

NOTICES OF MEMOIRS.

I.—Origin of the Ancient Crystalline Rocks.—Dr. Frank Dawson Adams gives an account of the excursion to the Pyrenees in connection with the Eighth International Geological Congress (Journ. Geol., 1901, ix, pp. 28–46). The object of the excursionists was to examine, under the leadership of Professor Lacroix, certain intrusive granite masses, which have not only intensely altered the strata through which they pierce but which have produced a wholesale transformation of the sedimentary rocks in question into granite, the granite now occupying the space formerly occupied by the sediments. The districts examined were Aix-les-thermes, L'Etang de l'Estagnet, L'Etang de Baxouillade, Cirque de Camp Ras, Foix, Arignac, Cabre, Vicdessos, Sem, Massat, Bagnères-de-Bigorre, Pouzac, Payole, Cirque d'Arbisson, and Barèges. While recognizing that the excursion was merely a rapid traverse of a district which has received detailed attention from the French petrographers, Dr. Adams sums up as follows: "While the transfusion of a certain amount of material into the limestones along the immediate contact of the intrusions and also a solution of the limestone to a limited extent in certain cases seems highly probable; the wholesale transformation of limestone into diorite, or of shale into gneiss and granite, which has been described in the case of these contact zones of the Pyrenees, is as yet very far indeed from being proved."

II.—Nodular Granite from Pine Lake, Ontario. By Frank Dawson Adams, Ph.D. (Bulletin of the Geological Society of America, 1897, vol. ix, pp. 163–172, pl. xi; February 10, 1898.)—Professor Adams, while carrying out some work for the Geological Survey of Canada in the eastern part of the Province of Ontario, has discovered a remarkable occurrence of orbicular or nodular granite in the township of Cardiff, in the county of Peterborough. In this part of the country the fundamental rocks are Crystalline Limestones, associated with Gneisses and Amphibolites, broken through by great intrusions of Granite. The nodule-bearing Granite occurs on the north and south sides of Pine Lake. It is rather fine-grained and usually gneissic in places, but often massive. The nodules are confined to a portion only of the Granite, and are not in proximity to the Amphibolite; and therefore the nodular structure is not a contact phenomenon. The nodules are spherical or ellipsoidal, and occur either scattered through the rock or, more rarely, in lines. When the nodules occur in rows they gradually get closer together until they seem to fuse or coalesce into a continuous band or vein. The centres of the nodules exhibit little segregation bunches of schorl. Professor Adams concludes that these nodules are due to a primary differentiation of the magma, for the reason that they do not include certain minerals such as Microcline, which have evidently crystallized from the magma latest, and which are abundant in the surrounding Granite; while on the other hand Sillimanite occurs in the nodules, being one of the first to separate from the magma, but does not occur in the surrounding Granite.—F. C.

III.—An Experimental Investigation into the Flow of Marble. (Philosophical Transactions of the Royal Society of London, 1901, vol. cxcv, pp. 363–401.)—These experiments have been carried out by Messrs. Frank Dawson Adams and John Thomas Nicolson; pure Carrara marble being the rock selected. The paper deals with the methods employed, deformation of the dry rock at ordinary temperature, at 300 C., and at 400 C., and at 300 C. in the presence of water. Comparison is made of the structures produced in Carrara marble by artificial deformation with those produced by deformation in the case of metals, and comparison of the structures produced with those observed in the limestones and marbles of highly contorted portions of the earth's crust. The following is the summary of results:—(1) By submitting limestone or marble to differential pressures exceeding the elastic limit of the rock and under the conditions described by the authors, permanent deformation can be produced. (2) This deformation, when carried out at ordinary temperatures, is due in part to a cataclastic structure and in part to twinning and gliding movements in the individual crystals composing the rock. (3) Both of these structures are seen in contorted limestones and marbles in nature. (4) When the deformation is carried out at 300 C. or, better, at 400 C., the cataclastic structure is not developed, and the whole movement is due to changes in the shape of the component calcite crystals, by twinning and gliding. (5) This latter movement is identical with that produced in metals

by squeezing or hammering, a movement which in metals as a general rule, as in marble, is facilitated by increase of temperature. (6) There is therefore a flow of marble just as there is a flow of metals under suitable conditions of pressure. (7) The movement is also identical with that seen in glacial ice, although in the latter case the movement may not be entirely of this character. (8) In these experiments the presence of water was not observed to exert any influence. (9) It is believed, from the results of other experiments now being carried out but not yet completed, that similar movements can, to a certain extent at least, be induced in granite and other harder crystalline rocks, and that several structures developed in these rocks in nature in highly contorted regions can thus be reproduced. Photo-micrographs of the marble are given.

IV.—Geology of West Cornwall.—Mr. J. B. Hill, who has been studying the geological structures of Western Cornwall for some years, has been talking to the Royal Geological Society of Cornwall about them. His paper has appeared in the Transactions (1901, vol. xii, pt. 6), and his conclusions, given in his own words, are as follows:—"The structures of the stratified formations in West Cornwall are identical with the structures of crystalline schists. In the Falmouth district, so far as yet examined, true slates have not been met with. The strata have been thrown into a series of isoclinal folds, accompanied by small faults. With these folds and faults minor structures have been set up until the whole rock has often become a mass of minute folds and thrusts, with their accompanying strain-slip cleavages. These processes have been carried so far that 'crush-conglomerates' have been produced on a large scale. It is evident, from a study of this district, that had the rocks been subjected to those stresses at a greater depth and below the zone of fracture, where they would not have been so free to move, they would have been converted into true schists. They possess now every structure of schists, but the mineralization has been wanting."

"The visible dip of the rocks is of no value, except as registering the inclination of the limbs of folds. As an illustration of this fact, it may be pointed out that although the strata have a general dip to the south-east, between Falmouth and Truro, we are apparently crossing the strike from the coast to the heart of the county, yet, instead of getting deeper in the stratigraphical series, we are on precisely the same geological horizon as at Falmouth, the intervening ground being made up of a succession of isoclinal folds."

This last paragraph is, we believe, confirmatory of De la Beche's view, and does not support the view sometimes expressed, that in this district we have a great thickness of sedimentary deposits.

V.—Argonaut from the Tertiary of Japan.—Mr. Yoshiwara has just published in *Annotationes Zoologicæ Japanenses* (1901, vol. iii, pp. 174–176) a description of a supposed new Argonaut from the Neogene tuff of Agenokimura, near Matsue, Iugori, province Izumo, Japan. This was found by Mr. J. Asāi, and mentioned by Professor

Jimbo as long ago as 1896 in the *Journal of the Tōkyō Geographical Society*, vol. viii. The specimens, of which there are two, can only be distinguished from '*A. tuberculosa*, Linn.' (said by Yoshiwara to be identical with *A. nodosa*, Sol., and *A. oryzata*, Mensh.), by the general outline of the shell, the size of the whorls near the centre, and the rows and numbers of the ribs. It is of considerable interest to find that this tuberculate form of the genus, which has never been found living in Japan, existed there in Tertiary times.

VI.—The Grand Canyon of the Colorado.—Professor W. M. Davis has published in the Bulletin of the Museum of Comparative Zoology at Harvard College (Geol. Series, v, No. 4, May, 1901) an account of an excursion to the Grand Canyon of the Colorado. His results may be summarized as follows:—"There is some probability that the San Rafael swell, like the Waterpocket flexure, is of pre-Tertiary origin. The other deformations of the region, both flexures and faults, are almost exclusively of much earlier date than the canyon cycle, and they may have been formed relatively early in the erosional history of the district. The total denudation of the region thus far accomplished may be considered in two parts, of which the first—the great denudation—was far advanced before the general uplift by which the second—the erosion of the canyon and the stripping of weak strata from the plateaus—was introduced."

"But the great denudation was complicated by repeated movements, after each of which the processes of erosion may have reached an advanced stage before the occurrence of the next series of disturbances. It is only by an analysis of these repeated movements and revived erosions that the origin of the drainage system can be determined. As far as this analysis can be attempted at present for the Grand Canyon district, the side streams seem to be of various origins, except that none of them appear to be antecedent. The Colorado itself may be in part antecedent to some of the many dislocations that the district has suffered, but it seems to be for the most part consequent on the displacements caused by faulting in the later part of the great denudation, and on the form that the surface had assumed at that time."

"The floor of the Toroweap valley is higher than the neighbouring valley floors, because it is sheeted with heavy lava flows which have effectively withstood the intermittent erosive effects of wet-weather floods. The past climate of the region cannot be safely determined; a change from a humid to an arid climate at the close of the Miocene does not appear to be demanded by the facts that have been appealed to in its support."

Professor Davis gives a bibliography and some illustrations, many of which are new, and one of which, a general photographic view of the Grand Canyon, is especially good. T. R. J.

VII.—Shorter Geological Notes.—Elkanah Billings, for twenty years palæontologist to the Geological Survey of Canada, and the founder of the *Canadian Naturalist and Geologist*, formed the subject of Dr. Ami's address as president of the Ottawa Field

Naturalists' Club, last December. The material has now been extended, a bibliography added, and the whole published in the *American Geologist* for May.

Professor E. W. Hilgard's "Historical Outline of the Geological and Agricultural Survey of the State of Mississippi," which appeared in the publications of the Mississippi Historical Society, has been reprinted in the *American Geologist* for May. It gives an interesting picture of the origin, rise, and progress of one of the United States Surveys, and provides an official account of the publications, always of value.

Mr. J. A. Cunningham has published a contribution to the Theory of the Order of Crystallization of Minerals in Igneous Rocks, in the Scientific Proceedings of the Royal Dublin Society (1901, vol. ix, pt. 4). The paper should be read in connection with Dr. Joly's paper, "Theory of the Order of Formation of Silicates in Igneous Rocks," published by the same Society in 1900.

REVIEWS.

I.—The Mineralogy of Scotland. By the late M. Forster Heddle, M.D., F.R.S.E. Edited by J. G. Goodchild, F.G.S. 2 vols.: 360 pp., 30 figures in text, 117 plates. (Edinburgh: David Douglas, 1901. Price 36*s.* nett.)

DURING the greater part of a long life the late Professor Heddle, for many years Professor of Chemistry in the University of St. Andrews, spent his holidays in the mineralogical exploration of his native country, and scarcely a single locality from which there was a likelihood of obtaining good specimens can have been left unvisited by him; he was thus able to bring together a collection of Scottish minerals remarkable for its completeness and for the excellence of its material; to its examination, chiefly chemical, he devoted all his available time. Some years ago the collection was purchased for the nation and deposited in the Museum of Science and Art at Edinburgh; there it was arranged and labelled, for public exhibition, by Dr. Heddle during the latter years of his life.

Of the topographical and chemical mineralogy of Scotland, Professor Heddle had thus an unsurpassed knowledge, and he made voluminous notes with a view to the eventual publication of a treatise by means of which the information so laboriously acquired might be preserved to posterity. Unfortunately, like too many other investigators, he was called to his rest when his work was still far from complete; there was thus a great danger that his notes might never be printed and made available for general use. His family has done what was possible to avert the threatened catastrophe, and have obtained help for the completion and editing of the work; the notes have been prepared for press and the treatise has been edited by Mr. J. G. Goodchild, who is now closely associated with the custody of the collection itself.

To complete the work, Mr. Alexander Thoms, son-in-law of

Professor Heddle, has compiled a list of the mineral species which have been found in each of the counties of Scotland; Mr. James Currie has prepared a list of Scottish Pseudomorphs, and an index of Scottish palæosomatic minerals; Mr. J. G. Goodchild has added an alphabetical list of minerals, indicating by means of asterisks those which occur in Scotland, and has further prepared a series of beautiful gnomograms and stereograms of the crystallographic forms of the more common mineral species.

The result is the issue of the two fine volumes now before us; the book is well printed, and illustrated regardless of expense; an excellent portrait of the author is given as frontispiece, and is followed by a short memoir. No more impressive memorial of Dr. Heddle could have been devised by his family.

The work is of course of the dictionary type, and designed, not for continuous reading, but for the purposes of reference; its usefulness depends, to a large extent, on the completeness and accuracy of the specification of the localities. No pains have been spared over this part of the book; all the places mentioned in Dr. Heddle's notes have been identified as far as possible, a tedious task, involving much difficulty and enquiry when the localities are remote from railways, are not recorded on the best maps, and are represented by names of which there is much diversity of spelling. Fortunately, Dr. Heddle had left a set of Ordnance Survey Maps, on which his annual wanderings had been traced; with the help of these, and much aided by the wide information of Mr. James Currie, Mr. Goodchild has prepared a Synonymic Index (33 pages) to the Scottish Mineral localities, specifying for each locality the position on the Ordnance Map and the names of the mineral species to be found there.

The numerous plates illustrating the forms of crystals have been prepared at great cost, and they add to the beauty of the volume; but Dr. Heddle left behind him no information as to whether the figures were original or not. Some, at least, were doubtless taken from works illustrating the minerals of other countries, though probably they at the same time illustrate Scottish minerals preserved in his own collection.

It should be mentioned that in the text there are numerous illustrations of agates, to the mode of origin of which Dr. Heddle had given much study.

It would add to the usefulness of the work if in a subsequent edition an alphabetical index to the mineral species and varieties, with page-references, were placed at the end of it.

II.—Homœomorphy among Jurassic Brachiopoda. By S. S. Buckman. Proc. Cotteswold Naturalists' Field Club, 1901, vol. xii, pt. 4, pp. 231–290, pls. xiii–xiv.

IN this paper Mr. Buckman performs a welcome service by drawing attention to the occurrence of what he terms 'homœomorphy' in Jurassic Brachiopoda. The part played by parallelism in producing striking similarities between members of separate

stocks has hitherto been sadly neglected, and the failure to recognize this independent acquirement of similar general features has doubtless repeatedly led to confusion. Two of the most striking examples of this phenomenon, described by the author, are furnished by *Terebratula imitator* and *Zeilleria subcornuta*, and by *Terebratula submalogaster* and *Zeilleria anisoclines*.

Some of the descriptions of new forms in this paper are unfortunately too brief, and might with great advantage have been amplified. The value of generic separations among the Jurassic Terebratuloids is, to some extent, admittedly a matter of personal opinion. But it may seriously be doubted whether any useful purpose is to be attained by the adoption of such a 'genus' as *Pseudoglossothyris*, proposed in this paper. It appears, at least, to be hardly justified by the somewhat slender distinctive characters embodied in the definition provided. Abuses of the word 'genus' are now unfortunately common, and there is a widespread and regrettable tendency to burden an already involved nomenclature by such additions.

The expression 'date of existence' scarcely commends itself when employed in relation to fossil shells. Doubt may be entertained whether the elaborate 'time-table' provided by the author can ever have more than a local value, and perhaps this is all that is claimed for it. For his useful and suggestive contribution to our knowledge of homœomorphy, Mr. Buckman is to be congratulated.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—May 8th, 1901.—J. J. H. Teall, Esq., M.A., V.P.R.S., President, in the Chair. The following communication was read :—

"The Influence of the Winds upon Climate during the Pleistocene Epoch: a Palæo-Meteorological Explanation of some Geological Problems." By F. W. Harmer, Esq., F.G.S.

Winds are an important factor in determining the distribution of climatic zones. Deviations of the isotherms from the normal are generally connected with the direction of the prevalent winds. The influence of marine currents is indirect rather than direct. Changes of wind cause marked and sudden changes in the weather, though the general direction of ocean-currents remains the same. Permanent alterations in climate during past epochs would have equally resulted from permanent changes in the wind. Anomalous weather is due to some unusual arrangement of high and low-pressure areas. Former cases of anomalous climate can only have occurred when the meteorological conditions were favourable.

Continental areas tend to be cyclonic in Summer and anticyclonic in Winter, while the reverse is broadly true of the oceans. During the Glacial Period ice-covered areas would have remained more or less anticyclonic throughout the year, while low-pressure areas must have prevailed in regions to the south of them and over the adjoining

oceans. This would have altered the prevalent direction of the winds and the distribution of rainfall; thus the anticyclone of the European ice-sheet may have caused cyclonic storms to pass farther south than at present, bringing oceanic winds over the Sahara, which formerly enjoyed a humid climate. Dead shells are rarely found now on the eastern shores of Norfolk and Suffolk, though they are driven on to the Dutch coast by westerly gales. Shell-débris in the Upper Crag-beds of East Anglia shows that easterly gales were common at that period. This may have been due to the altered path of cyclones, caused by the glacial conditions which were becoming established in regions to the north of Great Britain. The abundance of mammoth-remains along the shores of the Polar Sea and the alternate humidity and desiccation of the basin of Nevada may have resulted from allied causes.

It is difficult, however, to restore hypothetically the meteorological conditions of the Pleistocene epoch on the theory that the maximum glaciation of the eastern and western continents was contemporaneous. In that case an enormous anticyclone would have extended from the pole southward over both continents at the same time, causing cyclonic conditions in the Atlantic both in Summer and Winter. Such a condition of things would have flooded Western Europe with warm southerly winds. No such meteorological difficulties arise if the hypothesis that the more important glacial and interglacial periods alternated in the western and eastern continents be adopted. Thus persistent and excessive cold in North America during the Winter of 1898–99 was coincident with abnormal warmth in Europe; the winds were northerly and polar in America, southerly and strictly complementary in Europe.

On the other hand, the effect of an ice-sheet anticyclone extending from Greenland to Central Europe might have been to force the storm-tracks of the North Atlantic to the south-west, producing warm south-easterly winds in Labrador, which would have tended, moreover, to divert the surface-currents of the North Atlantic from the European to the American coast. The glaciation of Great Britain could only have happened at a time when the Icelando-British Channel was closed. No permanent ice-sheet could have existed in Britain and Scandinavia while the influence of the Gulf Stream was as it is at present.

It is possible that the shifting of glacial conditions from one side of the Atlantic to the other may have been due to differential earth-movements.

The views taken in this paper afford a simpler explanation of geological facts than those usually adopted. Instead of supposing that the climatic changes of the Great Ice Age, several times recurrent at intervals of a few thousand years, were due to astronomical or physical causes, it is suggested that the climate of the Northern Hemisphere being, from some unexplained cause, colder than that of our era, conditions of comparative warmth or cold may have been more or less local, affecting the great continental areas at different periods.

II.—May 22nd, 1901.—J. J. H. Teall, Esq., M.A., V.P.R.S., President, in the Chair.

Mr. George Abbott, in exhibiting some specimens of Cellular Limestone from the Permian beds at Fulwell, Sunderland, which he proposed to present to the British Museum (Natural History), remarked that their interest depended upon the assumption that they were entirely inorganic. Although showing a remarkable resemblance to corals, yet no zoologist or geologist had yet claimed them as organic. If this surmise were correct, the carbonate-of-lime-molecules—probably when amorphous—must have had some inherent molecular directive force which produced the numerous distinct patterns in their structure. These fall into four distinct classes—honeycomb (two kinds), coralloid, and pseudo-organic, the last-named being remarkable for having a constant discoidal shape, and therefore those of this class must have had their external form also controlled by the hypothecated force. Each class appears to have passed through four stages of 'growth' and to have undergone some marvellous rearrangements of the particles while in the solid condition. So far as he knew, no one had previously attempted to classify the different patterns, nor had anyone, except Mr. William King, in his work on "Permian Fossils," offered any theory as to the formation of this cellular structure in the Magnesian Limestone. (See Prof. G. A. J. Cole's letter, GEOL. MAG., April, p. 187.)

The following communications were read:—

1. "On the Skull of a Chiru-like Antelope from the Ossiferous Deposits of Hundes (Tibet)." By Richard Lydekker, Esq.

Twenty years ago the author proposed the provisional name of *Pantholops Hundesiensis* for an extinct species of antelope typified by an imperfect skull figured in Royle's "Botany, etc., of the Himalaya Mountains," pl. iii, fig. 1. The specimen is in the Museum of the Geological Society, and an examination has confirmed the original determination. The skull, although of rather smaller dimensions, comes very close to that of the existing chiru (*Pantholops Hodgsoni*) of Tibet in general form of brain-case, in the strong ridges marking the upper limits of the temporal fossæ, and in the contour of the occipital surface. The horn-cores have the same highly elliptical cross-section, and the same general setting-on and upright direction. The fossil apparently came from the horizontal deposits of Hundes, and its age is probably not greater than Upper Pliocene.

2. "On the Occurrence of Silurian (?) Rocks in Forfarshire and Kincardineshire along the Eastern Border of the Highlands." By George Barrow, Esq., F.G.S. (Communicated by permission of the Director of H.M. Geological Survey.)

These rocks occur in three lenticular strips between the schistose rocks of the Highlands and the boundary-fault next the Old Red Sandstone. The largest is about 20 miles long, and extends almost from Cortachy to beyond the Clattering Bridge; it is about ¾ mile wide at its widest. The rocks are divided into two groups: the Jasper and Green Rock Series below and the younger Margie Series

above. A section along the North Esk River is described in detail, and other sections referred to it. The lower division consists of fine-grained sandstones (bearing microcline), grey slaty shales, jaspers (sometimes containing circular bodies resembling radiolaria), and a variable series of basic igneous rocks ('green rock') of coarse texture and probably intrusive origin. The upper division consists of conglomerates, pebbly grits, dark and white shales, pebbly limestone, and grey shale. The age of the series cannot be definitely ascertained, but the lower division is compared with the Arenig cherts, etc., of the Southern Uplands, while the Margie Series is newer than this, but older than the Old Red Sandstone. Both groups have been much deformed, but the sediments contain clastic micas and have undergone practically no recrystallization, and the igneous rocks are never changed into hornblende-schists. The deformation is greatest near the junction with the Highland Schists, giving rise to a deceptive appearance of an upward succession and an apparent transition in crystalline character, but the crushing never extends more than a few yards into the Highland Series. A major thrust separates the Highland Schists from the Jasper and Green Rock Series, and a minor thrust generally separates the latter from the Margie Series. The position of the major thrust and that of the later great boundary fault skirting the Old Red Sandstone have been determined by the outer limit of the aureole of crystallization of which the South-Eastern Highlands form a part. The harder crystalline schists to the north-west have snapped off from the softer portions, now covered by newer rocks to the south-east.

3. "On the Crush-Conglomerates of Argyllshire." By J. B. Hill, Esq., R.N. (Communicated by R. S. Herries, Esq., M.A., Sec.G.S., with the permission of the Director of H.M. Geological Survey.)

While the sedimentary origin of the Highland Boulder-bed is proved by the foreign boulders contained in it, there occur in the Loch Awe region certain conglomerates, often along definite horizons, which may have been confused with it, but which the author is able to prove have originated by crushing. The sedimentary rocks of the area include all the members of the Loch Awe Series, consisting of grits, slates, and limestones, the latter being mostly gritty in character. Associated with these is an enormous amount of igneous material of Dalradian age, ranging from intermediate to basic in composition, together with porphyrite-dykes probably of Old Red Sandstone age and a plexus of Tertiary dykes. The sediments are everywhere folded, the folds being of isoclinal type. The Dalradian igneous material consists of epidiorites; and evidence is brought forward to prove that these rocks are intrusive, while their great apparent bulk is probably to be accounted for by repetition due to folding. A petrographical description is given of the various types of rocks represented among the epidiorites, the minerals of which include hornblende and felspar, with chlorite, epidote, calcite, quartz, and iron-ores. There is every gradation in texture from a coarse

gabbro-like type to the finest schists, and some of the rocks are vesicular. The rocks are frequently foliated.

The crush-conglomerates have been observed in the limestones, quartzites, and epidiorites; but they are most conspicuously developed at the junction of rocks of dissimilar character, and especially when the limestone and epidiorite are in juxtaposition. The junction of the two rocks is intricately folded: folded knobs of epidiorite measuring from a few inches to a foot or more being packed together in a limestone matrix. In the sections big blocks may be seen in process of division by shearing movements, which have succeeded the folding. The limestone seems generally to have played the part of a plastic body, and has accommodated itself as a matrix to the folded and isolated fragments of epidiorite, between which it has been squeezed. Thus the origin of the conglomerate is satisfactorily proved by the fact that it contains fragments of rocks newer than the sediments in which the crush-conglomerates are embedded. The author considers that it would be safer to regard such conglomerates in this area as have a calcareous matrix as having been formed by crushing.

CORRESPONDENCE.

THE *MAMMILLATUS*-ZONE IN EAST SURREY.

Sir,—In a short communication to this Magazine for May, 1899 (pp. 234–5), evidence was brought forward of the persistence of the zone of *Hoplites interruptus* along the Gault outcrop through Kent and Surrey. Since then Mr. Jukes-Browne's valuable memoir on the English Gault and Upper Greensand has appeared, and in this certain beds at the extreme base of the Gault in West Kent and East Surrey are considered as probably belonging to the lower zone of *Acanthoceras mammillatum*, though palæontological evidence of this is wanting. This evidence can now fortunately be supplied. About a mile and a half south-south-east of Merstham, at a point marked on the new 1-inch sheet 286 as "Stocklands Farm," there is a small brickfield where the extreme base of the Gault is dug. The junction with the Folkestone sands is not actually seen, but these sands are dug within a few yards of the section. In the lowest part of the clay there are abundant large and irregular phosphatic nodules, full of glauconite grains and with many quartz-grains also. In these nodules fossils occur, including two species of Ammonites, *Acanthoceras mammillatum* and *Desmoceras Beudanti*, the latter being particularly abundant. (These determinations have been kindly verified by Mr. Crick, of the Natural History Museum.) Other fossils occur, but not abundantly, and I cannot give a list, as most of them were dispersed among a party of my students before the special interest of the section was discovered. Coniferous wood occurs abundantly, beautifully preserved.

The section is closely similar in appearance to one at Reigate, described in Proc. Geol. Assoc., vol. xvi, p. 162, and there said to be unfossiliferous. On a recent visit, however, I found a piece of

coniferous wood there just like that at Stocklands, but no Ammonites. I would suggest to local geologists the advisability of a persistent search for the latter. A. M. Davies.

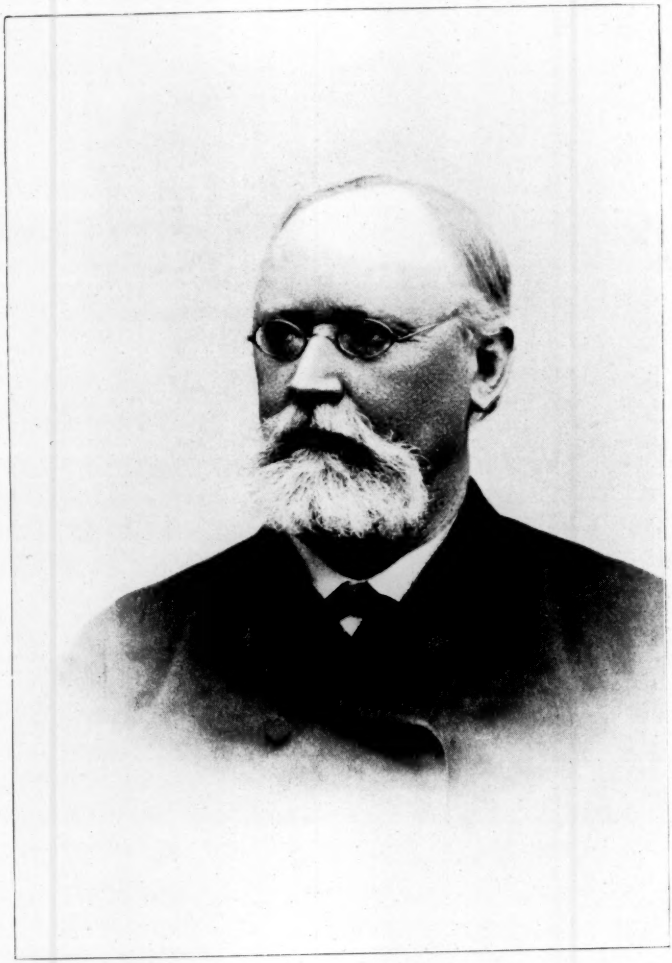
25, Mortimer Street, W.

NAMES FOR BRITISH ICE-SHEETS.

Sir,—To discuss fully the wide questions raised by Mr. Lamplugh's reply to my letter of last April would require far too much space, so I content myself with repeating that to propose a name for that which has not been proved to exist is, to say the least, premature. It is also objectionable, because so many persons cannot become familiar with a name without assuming that it implies the existence of a reality. As man is naturally prone to idolatry, which in the present age commonly takes the form of phrase-worship, I am sure that if the North Sea Ice-sheet passed without protest it would quickly materialize into a geological fact. I had no objection to using the term 'Scandinavian Ice-sheet,' because something of the kind must have existed in that country, yet I was careful to speak only of 'Caledonian ice.' So I cannot allow Mr. Lamplugh to smuggle in an East British Ice-sheet under the cover of any phrase in my letter. As for the late Glacial age of the Dogger Bank, that of course is possible; but I think whoever makes use of it as an argument should indicate under what circumstances such a long shoal-like mass of morainic matter was deposited in that position. Also, I should like to have an explanation of the causes which would lead to an exceptional precipitation of snow on any particular part of a comparatively level plain which had considerable land masses on three sides. My complaint against the school of glacialists to which Mr. Lamplugh belongs is, that they insist on those facts which seem to favour their ideas and ignore all which have the contrary effect. Thus, like the defenders of the Ptolemaic system of Astronomy, they support hypothesis by hypothesis, and invent epicycles to escape from difficulties. It is, however, a gain to have it admitted that boulders did not take an inside or outside passage on an ice-sheet the whole way from Scandinavia to Eastern England. This encourages me to hope that a course of sea-bathing early in the Glacial Epoch may embolden some geologists to repeat the process later in the same, and to extend southward the submergence which must have occurred then (Geol. Mag., 1877, p. 72, and 1900, p. 289) in a more northern region. T. G. Bonney.

CURIOUS BRECCIAS IN THE HIGHLANDS.

Sir,—There are in the Scottish Highlands between Loch Katrine and the upper part of Loch Lomond several bosses of diorite surrounded by brecciated schist. These are very curious, for each boss of diorite is surrounded by a narrow fringe of breccia consisting entirely of schist without any admixture of igneous matter. It seems to me that the diorite must have been forced up in a solid state through the schist, which in consequence got broken up; for had the diorite been in a molten state when it came up, some of it would surely have flowed among the fragments of schist.



Yours
very truly
G. Lindström

Further north, in Glenfalloch, there is a more extensive area of similar brecciated schist, where, however, as far as I remember, no igneous rocks are to be seen.

The researches of Lapworth, Peach, and Horne in the Highlands, of Lamplugh in the Isle of Man, and of others elsewhere, have taught us that solid rocks have been broken up or ground into powder by mechanical violence on a far larger and more extended scale than had been previously dreamed of.

If I am right in my conjecture as to the origin of the breccias mentioned above, they are instances of the same sort of thing.

June 4, 1901. J. R. Dakyns.

P.S.—I am reminded by my friend, Mr. C. T. Clough, that the breccias may be due to explosions. They are mentioned by Sir Archibald Geikie in his work on "Ancient British Volcanoes," but I have not the book at hand to refer to.—J. R. D.

OBITUARY.

GUSTAF LINDSTRÖM.

(WITH A PORTRAIT, PLATE XIII.)

Born at Wisby, Aug. 27, 1829. Died at Stockholm, May 16, 1901.

How vividly comes to one's mind that little room looking into the courtyard of the Riksmuseum at Stockholm, with its plain deal floor, deal tables and writing-desk, and the rough deal shelves for books covering three of its walls, the only decoration a few portraits (as of Angelin and Darwin), the only sign of comfort an old horse-hair sofa. Here for twenty-five years, day after day, Gustaf Lindström pursued his quiet labours on that wonderful collection stored in the adjoining room, a collection rich chiefly in the fossils of Silurian Gotland amassed by the successive exertions of Hisinger, Angelin, and Lindström himself. At one of the windows in that room, overmuch darkened though it was by the tall houses opposite, one would see G. Liljevall developing some rare fossil or making those exquisite drawings that illustrated Lindström's papers; at another window the attendant boy, usually a Gustaf too, made cardboard trays or sorted out new accessions; while a third window was generally occupied by some foreign palæontologist who had journeyed far to study the famous collection. Many are there of these who to-day mourn Lindström, not merely as a leader gone from among them, but as an ever attentive host, and as a dear friend.

Born among the mediæval ruins of Wisby, in whose cliffs and on whose strand fossils are to be had for the mere taking, the meditative and retiring youth could not fail to have his interest aroused by the relics of the past. He might have been a great archæologist, in fact his academic thesis was on the history of his native island in Queen Christina's reign, and in after years he published two thick volumes on the Middle Ages in Gotland; but the direct incentive to palæontological studies was early furnished. "In 1845," he once wrote, "when I was quite a boy, much wondering at the marvellous things I saw enclosed in the limestone rocks of my native island of Gotland,

Sir Roderick, accompanied by M. de Verneuil, visited the island and ranged its strata, along with the other old 'transition rocks' of Sweden, in his newly-founded realm 'Siluria.' This fact acted upon me as a fresh revelation, and indicated the path upon which to proceed." It was no doubt also Murchison's visit which suggested his enquiry into the elevation of Gotland, the subject of his first paper (1852).

But Lindström, though he continued to the last to study the geological relations of the Gotland rocks, did not become a mere stratigraphical palæontologist. In 1848 he commenced student at Upsala University and took the opportunity of attending a course of lectures delivered by Lovén in Stockholm. Thus was impressed on him the need to the palæontologist of a thorough understanding of living animals, and so, after taking his doctor's degree in 1854, he served for a time as extraordinary amanuensis at the zoological museum of the University, and published purely zoological papers—on the invertebrate fauna of the Baltic, on the larva of *Peltogaster*, and on the development of *Sertularia*. In 1856 he accepted a post as school-teacher in Wisby, and in 1858 a mastership at the Grammar School in that town. During these years he translated a textbook of zoology by H. Masius, and produced his "Geologiens Grunder," which was an adaptation of the works of Lyell to Swedish students, and contained numerous original illustrations from the geology of Sweden; it speedily ran through two editions, and did much to increase the study of geology in that country.

Now settled in Wisby, Lindström, without dropping his zoological researches, as proved by a paper on the fish of Gotland (1867), devoted more attention to the fossils of the island. He began with the Brachiopoda (1860), but soon turned to the Cœlentera, and in 1865 published the first of that valuable series of papers on the rugose corals which led up to his memoir on the operculate corals of the Palæozoic formations (1883). These papers, while disclosing hitherto unsuspected facts of coral structure, finally solved the problem of the systematic position of the peculiar *Calceola*, previously regarded as an aberrant brachiopod. A remarkable type of madreporarian was fully described by him in 1868 under the name *Calostylis*, and again discussed in his memoir on the Anthozoa perforata of Gotland (1870). He wrote also on the tabulate corals, and was at the same time investigating the deep-sea corals of the Atlantic. To complete the account of his work on the corals, we may mention his papers on Silurian corals from Russia (1882), on *Rhizophyllum* (1884), on *Prisciturben* (1889), on the 'Corallia baltica' of Linnæus (1895), a description of some Silurian corals from Gotland, including the new genera *Nodulipora*, *Holophragma*, and *Dinophyllum*, with re-descriptions of his *Helminthidium*, *Pachypora*, *Polyorophe*, *Actinocystis*, and others (1896), on a *Tetradium* from Beeren Eiland (1899), on the Neocomian *Thecocyathus Nathorsti* from King Charles Land (1900), and his great memoir on the Heliolitidæ (1899).

But before these last-mentioned papers were written occurred the death of the Keeper of the fossil Invertebrata in the State Museum at Stockholm, N. P. Angelin, and the Academy of Sciences appointed

Lindström to the post (1876). One of his first tasks in this new and more favourable position was the completion and publication of the "Fragmenta Silurica" (1880), for which some plates had been prepared by Angelin. There also fell on him the difficult and ungrateful labour, shared with Lovén, of editing Angelin's "Iconographia Crinoideorum." These tasks accomplished, Lindström found time to attack other groups of Gotland fossils. Thus, in 1884 we have from him a beautifully illustrated memoir "On the Silurian Gastropoda and Pteropoda," of importance as indicating the varying nature of the fauna in correspondence with the varying conditions in different parts of the Gotland sea. In 1885 he issued a revision of the trilobites and Merostomata, containing descriptions of many new species, while in the same year he was associated with T. Thorell in a publication that awoke profound interest, namely, the description of a scorpion, *Palæophonus nuncius*, from a bed of Lower Ludlow age at Wisby.[1] This was the oldest air-breathing animal then known, but there have since been described *Proscorpius*, Whitfield, from the Waterlime group of New York, *Palæoblattina*, Brongniart, from the Middle Silurian of Calvados, and *Protocimex*, Moberg, from the Upper Ordovician of Sweden. He then turned his attention to the remains of Cephalopoda preserved in a hard, splintery limestone of Southern Gotland, and requiring the utmost patience for their extraction and elucidation. The result of this was the important memoir on "The Ascoceratidæ and the Lituitidæ," in which he lucidly explained the complicated structure of that extraordinary nautiloid, *Ascoceras*. The year 1895 produced another discovery of the greatest interest, namely, a *Cyathaspis* from beds of Lower Wenlock age at Lau in Gotland; the minute structure of the plates was very fully described by Lindström.

These important memoirs by no means exhausted the activities of Professor Lindström. He visited Gotland every summer and pursued his enquiries into its geology, as many minor papers bear witness. On these wanderings through the island he also collected the materials for his archæological studies. He published a list of the fossils of Gotland, followed by lists of the Cambrian, Ordovician, and Silurian faunas of Sweden. He took an active part in the affairs of the Academy, and occasionally gave popular lectures on subjects of general geological interest. Of recent years, as the burden of age began to press more heavily, he rejuvenated himself (as he expressed it) by visits to Italy, in which both as naturalist and archæologist he took the greatest possible delight. But this did not cure the gradual failure of eyesight that was his greatest trouble, and rather more than two years ago he finally lost the use of one eye. When I saw him last, in 1899, he was dreading the loss of the other, but was still hard at work, and greatly excited over an important discovery just made in the trilobites. Oddly enough, this concerned certain maculæ, believed by him to be vestigial eye-spots, occurring on the hypostome of many genera. This gave rise to the last paper he ever wrote, a wonderfully detailed study of these maculæ and of the

[1] Another Silurian scorpion, referred to Lindström's genus *Palæophonus*, has been discovered by B. N. Peach at Lesmahagow, Lanarkshire.